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HANDBOOK OF OPERATION AND SERVICE INSTRUCTIONS

TYPE B

ELECTRONIC CONTROL SYSTEMS TURBOSUPERCHARGER

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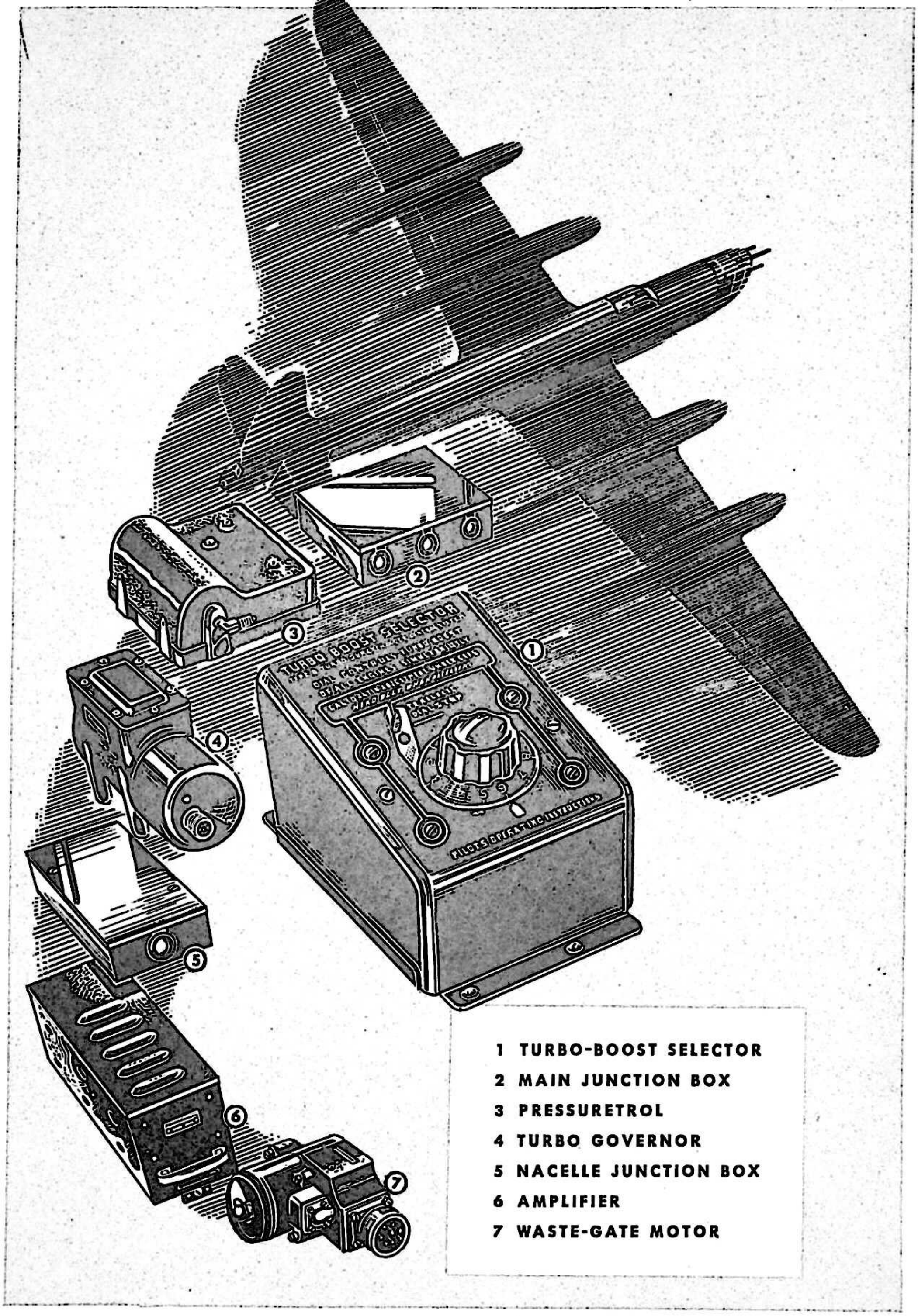
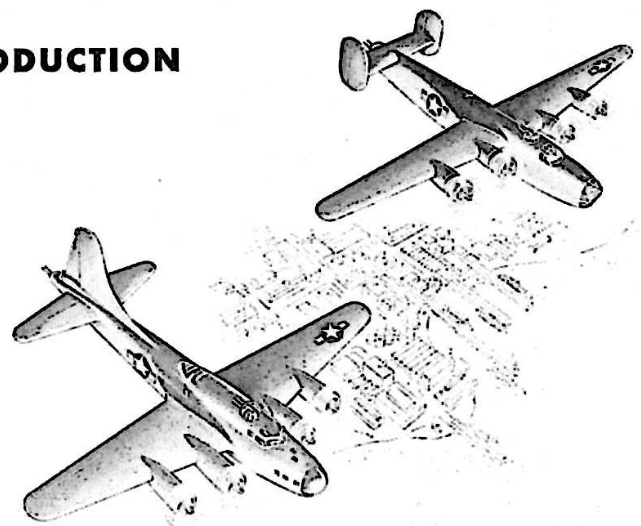


Figure 1—Individual Units of the Type B Control System for Turbosuperchargers

Section I

INTRODUCTION



1. This handbook is issued as the basic instructions for the operation and service of the Type B Electronic Control System for Turbosuperchargers.

2. The equipment described in this handbook is manufactured by the Minneapolis-Honeywell Regulator Company, Minneapolis, Minnesota, under contract number W535 ac-32799, Specification No. 28469A and 28472A.

3. The information contained herein is also applicable to the Type B Electronic Control System for Turbosuperchargers manufactured by R. C. Allen Products, Incorporated, Grand Rapids, Michigan, under Contract No. W20-017 ac-165.

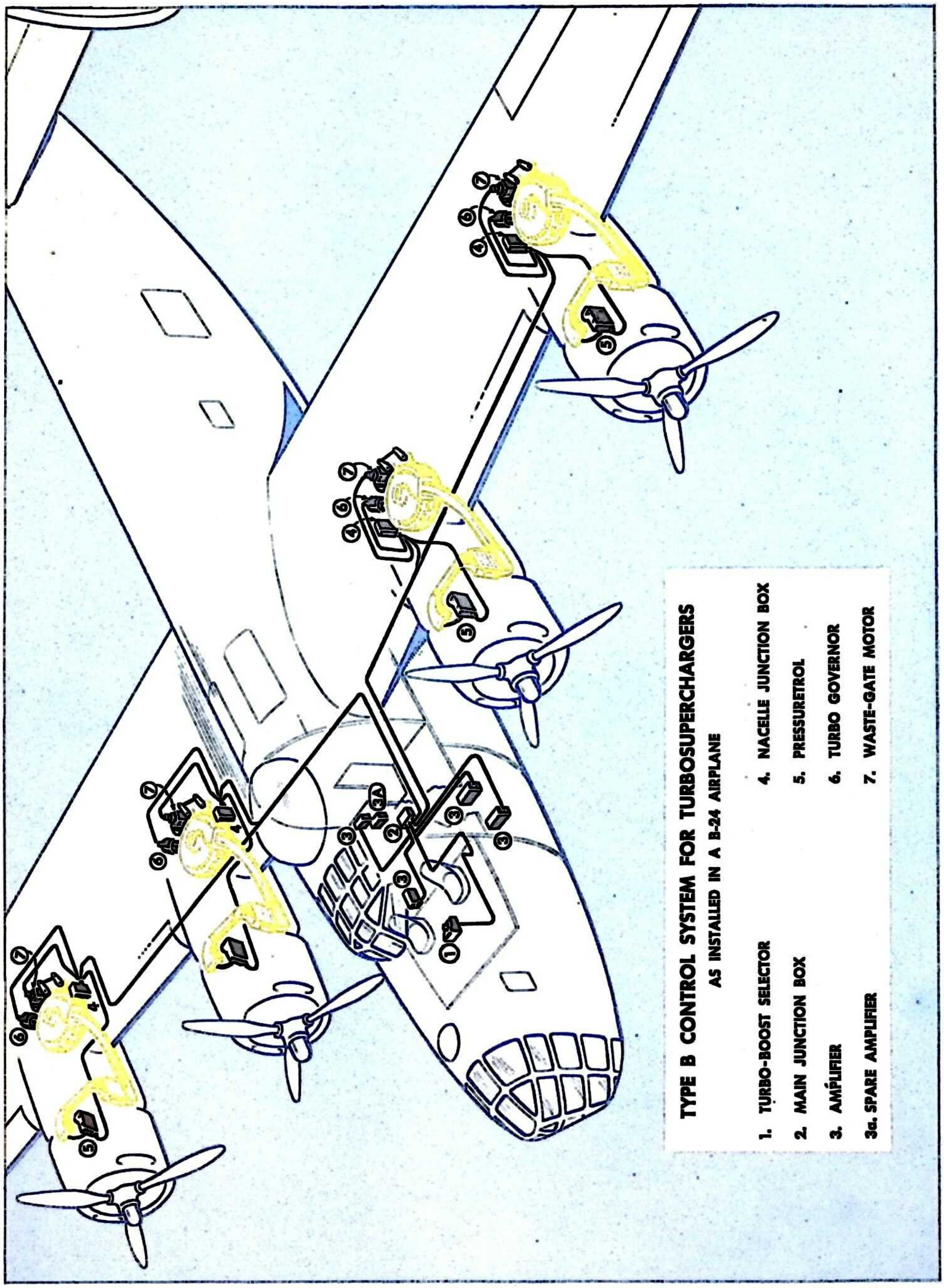
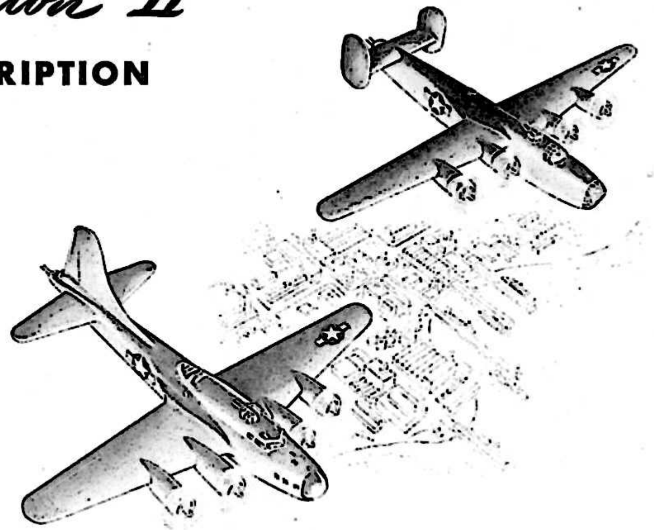


Figure 2—Schematic Layout of the Turbosupercharger Control System in a B-24 Airplane

Section II

DESCRIPTION



1. GENERAL DESCRIPTION.

a. MAJOR ASSEMBLIES.—The type B control system for turbosuperchargers consists of a number of individual control units electrically interconnected to operate as a system. Thus, a single-engine installation of the turbo control system includes a waste-gate motor, an induction-system Pressuretrol, an amplifier, a turbo governor with its flexible drive, a turbo-boost selector, a nacelle junction box, and a main junction box. In a multi-engined airplane, as shown in figure 2, the installation includes one turbo-boost selector and one main junction box, *plus* one complete set of the other units for each engine.

The complete system is operated on 115-volt, 400-cycle alternating current supplied by the airplane's inverters. Power required is 67 volt-amperes (.8 power factor). Running and standby requirements are nearly the same.

b. IDENTIFICATION OF THE UNITS BY NUMBER.—The units of the type B control system for turbosuperchargers are identified by the following class 03E stock numbers.

Name of Unit	Stock Number
Complete system	G1059A
Turbo-boost selector (manifold-pressure selector)	
with case, threaded shaft	4400-G1056A1
with case, flat shaft	4400-G1056A3
Turbo-boost selector	
without case, threaded shaft	4400-G1056A2
without case, flat shaft	4400-G1056A4
Induction-system Pressuretrol 16 to 34 inches Hg pressure range	4400-G16A2
Turbo governor	
2460 rpm—for type B-2 turbosupercharger	4400-G1057A3
2780 rpm—for types B-11 and B-22 turbosuperchargers	4400-G1057A4
Waste-gate motor	4400-G303AY2
Amplifier	4400-G403A1
Amplifier rack	4400-G1060A1
Main junction box	4400-G1066A1
Nacelle junction box	4400-G1065A1
Flexible drive	
5½ inches long for B-24 airplanes	4400-G1075A1
10 inches long for B-17 and B-29 airplanes	4400-G1075A2

c. FUNCTION OF THE SYSTEM.—The purpose of the type B control system for turbosuperchargers is to maintain constant carburetor inlet pressure by automatically regulating the position of the exhaust waste gate. How this is done and the advantages gained thereby are explained in the following paragraphs and illustrations.

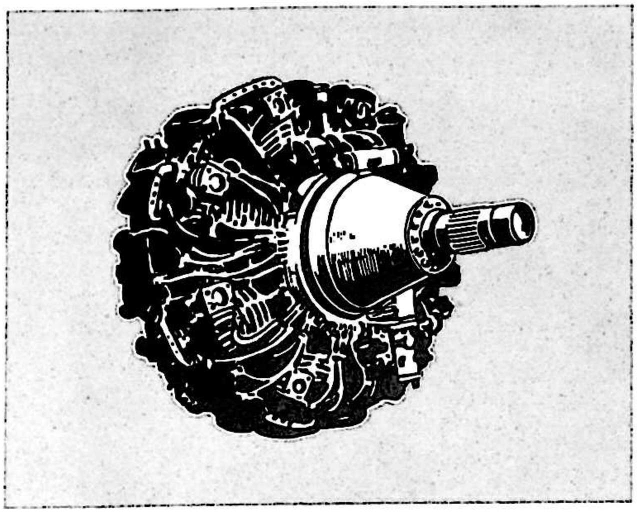


Figure 3—The Airplane Engine

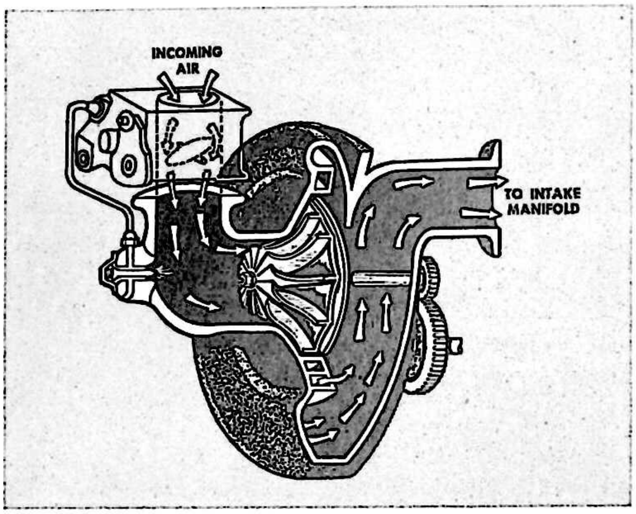


Figure 4—Internal Blower Increases Manifold Pressure

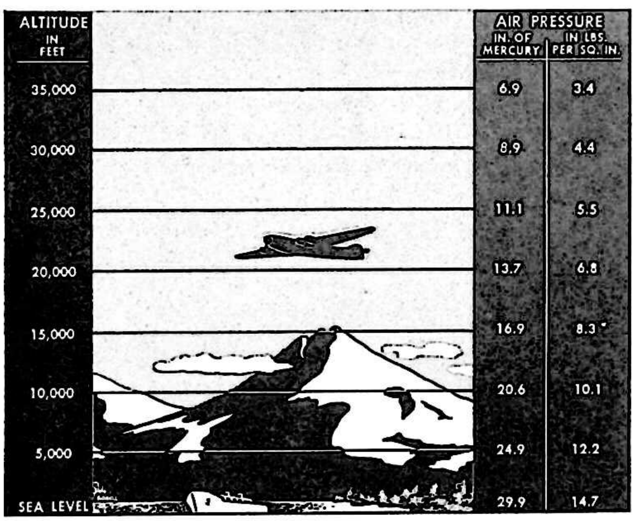


Figure 5—Pressure Drops as Airplane Rises

(1) MAINTAINING ENGINE HORSEPOWER THROUGH TURBOSUPERCHARGER REGULATION

(a) The horsepower output of an engine depends on the total weight of fuel-air mixture entering the cylinders each second. In a given engine, the weight of fuel-air mixture entering the cylinders per second depends upon manifold pressure. Thus, for constant horsepower output, it is necessary to maintain constant manifold pressure.

(b) To obtain greater power from a given engine, it is desirable to keep the manifold pressure above atmospheric pressure. This pressure boost is accomplished with a built-in gear-driven internal blower. The pressure boost derived from this blower at any given engine speed depends upon the pressure at the blower intake.

(c) Since atmospheric pressure decreases at higher altitudes (figure 5), the pressure at the blower intake also decreases, causing a corresponding reduction of manifold pressure and horsepower. Only by maintaining constant pressure at the intake side of the internal blower can manifold pressure be held constant and horsepower maintained at high altitudes.

(d) This is accomplished with the turbosupercharger, a centrifugal air compressor, driven by a turbine in the exhaust stack. The turbosupercharger compresses the air from the atmosphere and feeds it to the internal blower. The pressure boost derived from the turbosupercharger is limited only by the safe operating speed of the turbine wheel.

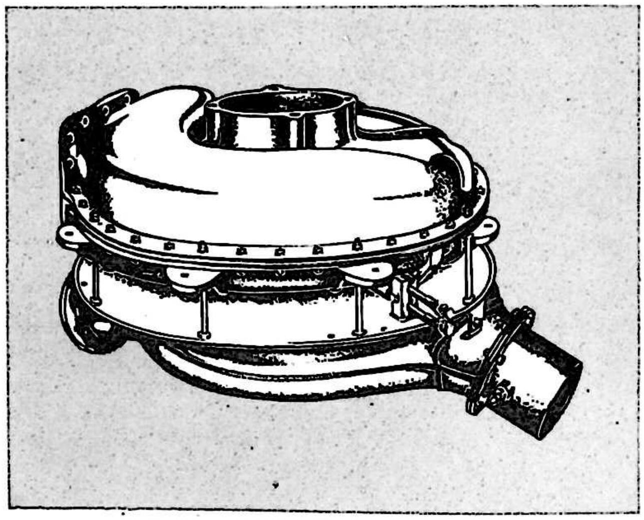


Figure 6—The Turbosupercharger

(e) The speed of the turbosupercharger is regulated by opening and closing the exhaust waste gate. When the waste gate is open, it permits exhaust gases to escape without passing through the turbine; when closed, it blocks the escape of gases, forcing them to impinge against the turbine wheel and spin the compressor. Thus, the amount of turbo boost may be regulated to suit the requirements of the engine at any altitude.

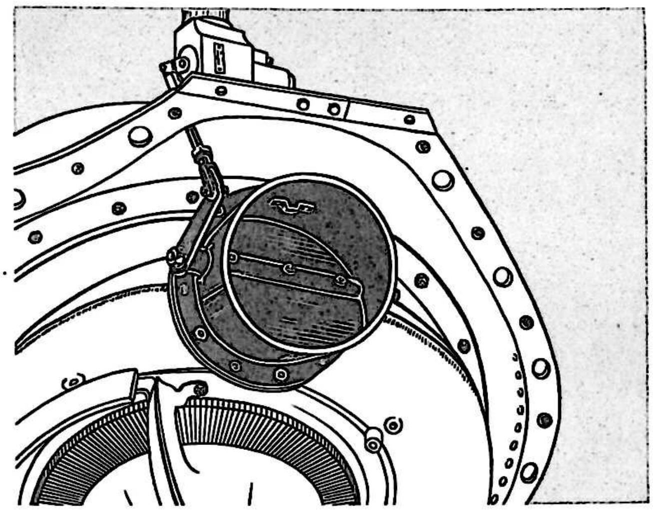


Figure 7—The Waste Gate

(f) The type B control system for turbosuperchargers employs a two-phase reversible electric motor to position the waste gate through a mechanical linkage. Operation of the waste-gate motor is automatically controlled by electrical signals from the turbo-boost selector, the Pressuretrol, and the turbo governor. These signals, amplified and analyzed by the amplifier, control the power delivered to the waste-gate motor.

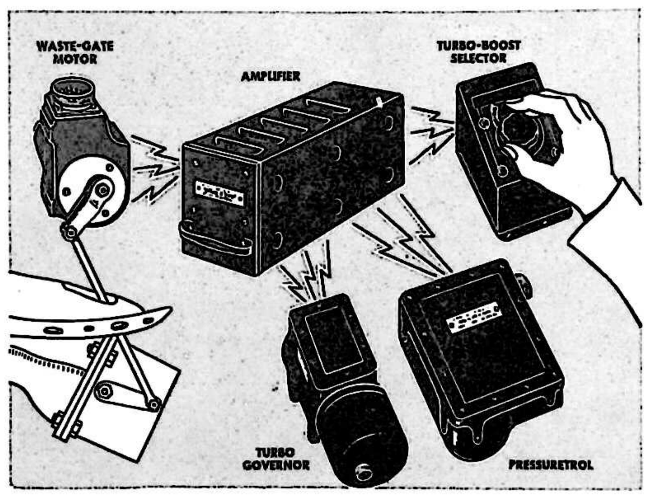


Figure 8—The Turbosupercharger Control System

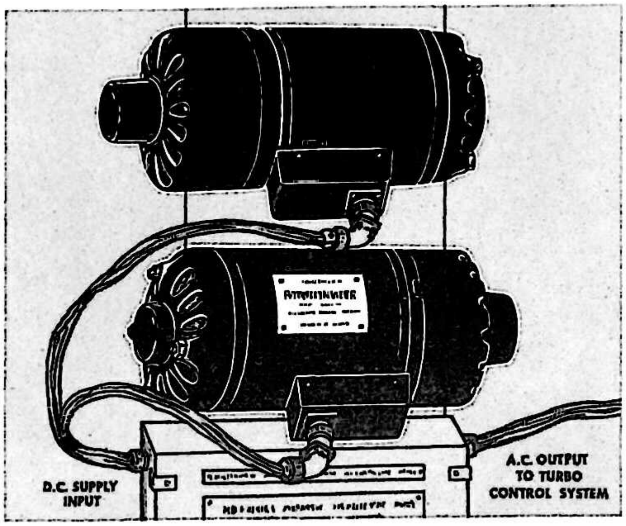


Figure 9—The Airplane's Inverters

(g) The source of all electric power used by the turbosupercharger control system is one of the airplane's 400-cycle inverters. Although two such inverters are installed in the airplane, only one is used at a time. Either inverter supplies the 115-volt, 400-cycle alternating current needed by the turbo control system.

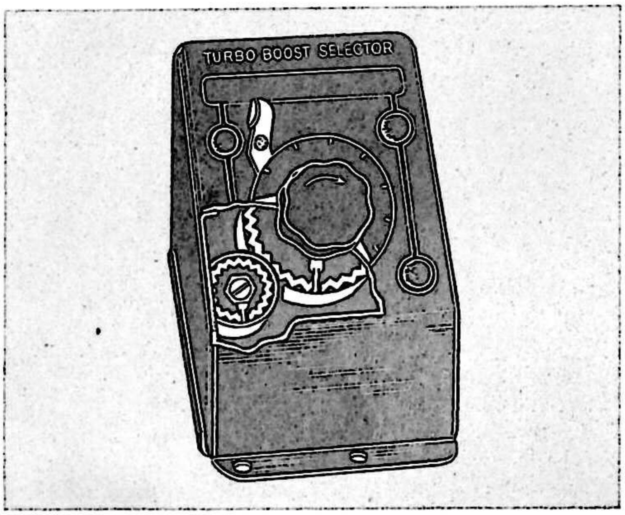


Figure 10—Turbo-Boost Selector

(h) The turbo-boost selector is the pilot's control device by which he regulates the operation of the turbo control system. It contains four small calibrator potentiometers which require adjustment only to compensate for small differences in engine or turbo performance. Once the calibrators are set, the pilot can control the turbo boost on all four engines simultaneously by turning the large central control potentiometer.

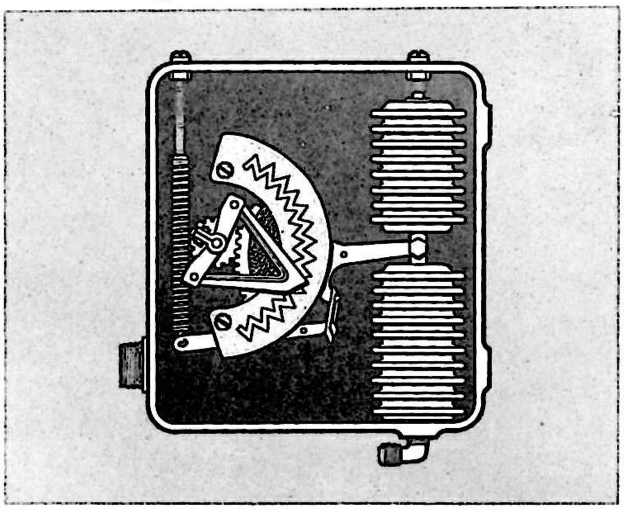


Figure 11—Induction-System Pressuretrol

(i) The Pressuretrol is the sensing element which measures electrically the pressure of the air supplied by the turbo to the carburetor. This unit controls the automatic operation of the system to maintain whatever pressure the pilot has selected, regardless of changes in atmospheric pressure caused by variations in the airplane's altitude.

(j) The turbo governor is a dual safety device driven by a flexible drive shaft, which is geared to the turbosupercharger. One part of the mechanism, called the overspeed control, prevents the turbo from exceeding its safe operating speed limit. The other part, the accelerometer, anticipates the pressure increase from turbo acceleration and provides a signal to start opening the waste gate in time to prevent overshooting of manifold pressure.

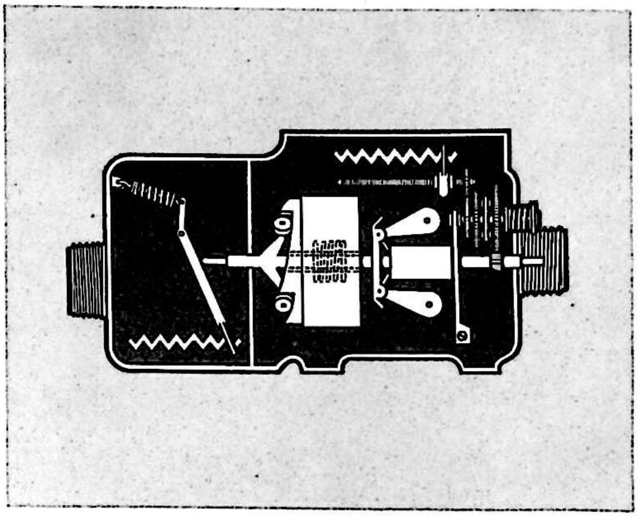


Figure 12—The Turbo Governor

(k) The amplifier is an intermediate unit between the control units and the waste-gate motor. It receives two kinds of signals from the other control units. One kind calls for rotation of the waste-gate motor to close the waste gate; the other, for rotation to open the waste gate. After amplifying the signal, the amplifier determines the direction of waste-gate movement called for and controls the power delivered to the waste-gate motor accordingly.

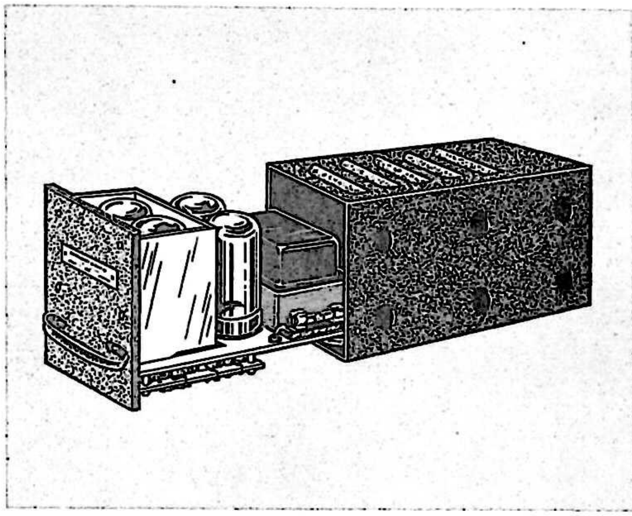


Figure 13—The Turbo Amplifier

(l) When the waste-gate motor operates the waste gate in response to the control signals, it also operates a balancing potentiometer which produces a signal opposed to the original control signal. When the rotation of the motor is enough to make the two signals exactly neutralize each other, the power from the amplifier is cut off, and the waste-gate motor stops. Thus the amount of waste-gate movement is determined by the size of the original control signal.

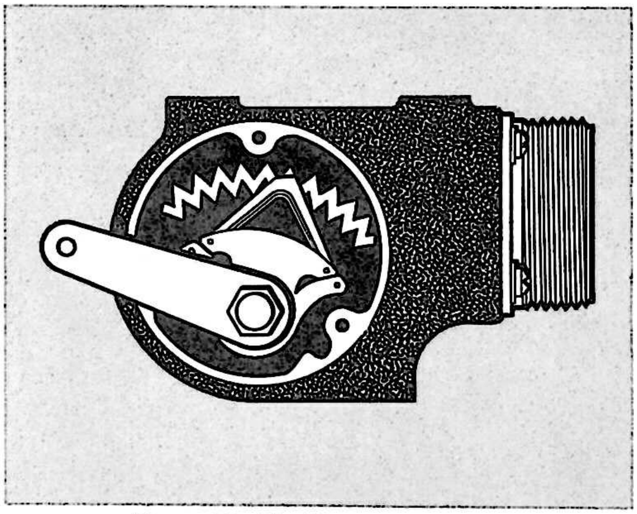


Figure 14—The Waste-Gate Motor

2. DETAILED DESCRIPTION.

a. TURBO-BOOST SELECTOR.—The turbo-boost selector, previously called the manifold-pressure selector, is the manual control unit of the system. It is used by the pilot or copilot to select the carburetor inlet pressure necessary to produce the desired manifold pressure for any flight condition. The other control units of the system, except those which act as protective controls, operate to hold pressures at the level selected with the turbo-boost selector.

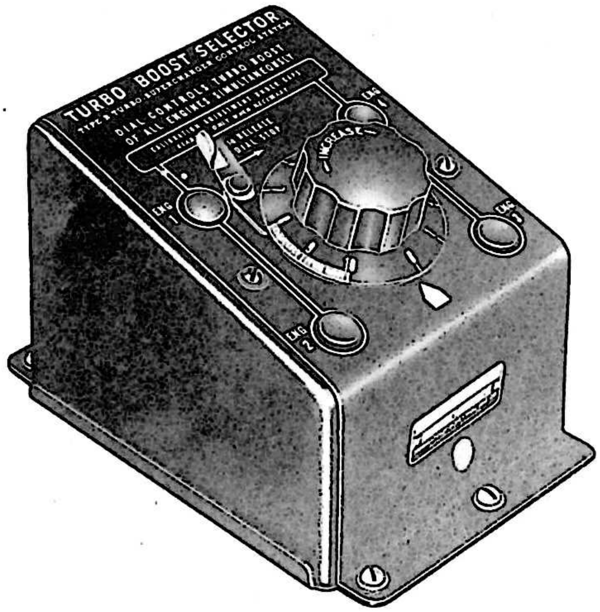


Figure 15—Turbo-Boost Selector

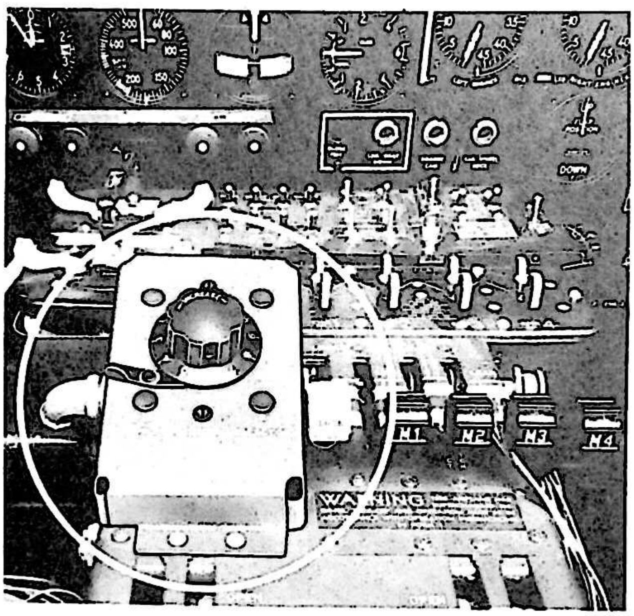


Figure 16—Turbo-Boost Selector in B-17 Cockpit, Factory Installation

On multi-engine airplanes, the turbo-boost selector also provides a means of synchronizing manifold pressures of all engines. This is accomplished by adjustment of calibrator potentiometers, one potentiometer in the control circuit for each engine.

(1) DETAILS OF CONSTRUCTION.

(*a*) HOUSING AND EXTERIOR.—The turbo-boost selector is a rectangular aluminum box with slanting top and a dull black finish. (See figure 15.) For some installations it is furnished without the case. In B-17 factory installations the unit is mounted in a case furnished by the airplane manufacturer. (See figure 16.) In B-29 installations, no case is used, as the unit is mounted inside the control pedestal.

Carburetor inlet pressure, and therefore manifold pressure, is set by turning the knob (A, figure 17) and dial (B) on top of the unit. Turning the knob clockwise calls for a closed waste gate, which increases manifold pressure.

The dial is graduated from "1" to "10," with a reference arrow below the dial. These graduations are used for relative position only, and do not refer to absolute pressure values. In practice, "8" is usually calibrated for maximum take-off power. (See section III, paragraph 5.) This is referred to as "military power." A latch (D) which stops the dial at "8" must be released before the dial can be turned beyond that point. The latch slides lengthwise slightly on its pivot, so it will drop above the dial-stop notch (C) when it is tripped. Therefore, the latch does not have to be held when the dial is turned beyond "8," allowing the unit to be operated with one hand.

Since the range above "8," represented by "9" and "10," provides manifold pressures in excess of the mean effective pressure for which the engine is designed, this range should not be used except in emergencies. It is "red-lined" and marked "EMERGENCY POWER RANGE."

Four snap plugs (E) cover the calibrators within the unit. (See paragraph (*c*) following.) The AN-connector receptacle is mounted on the bottom of the unit from the inside.

(*b*) SELECTOR POTENTIOMETER ASSEMBLY. (See figure 17.)—The selector potentiometer assembly consists of a large cylindrical winding (F) and a wiper (I) which contacts the winding on its inner surface. The wiper is mounted on the wiper shaft (H) which is turned by the knob through the vernier drive shaft (G) and gears (K) of approximately 1:3 ratio. The knob is fastened to the vernier

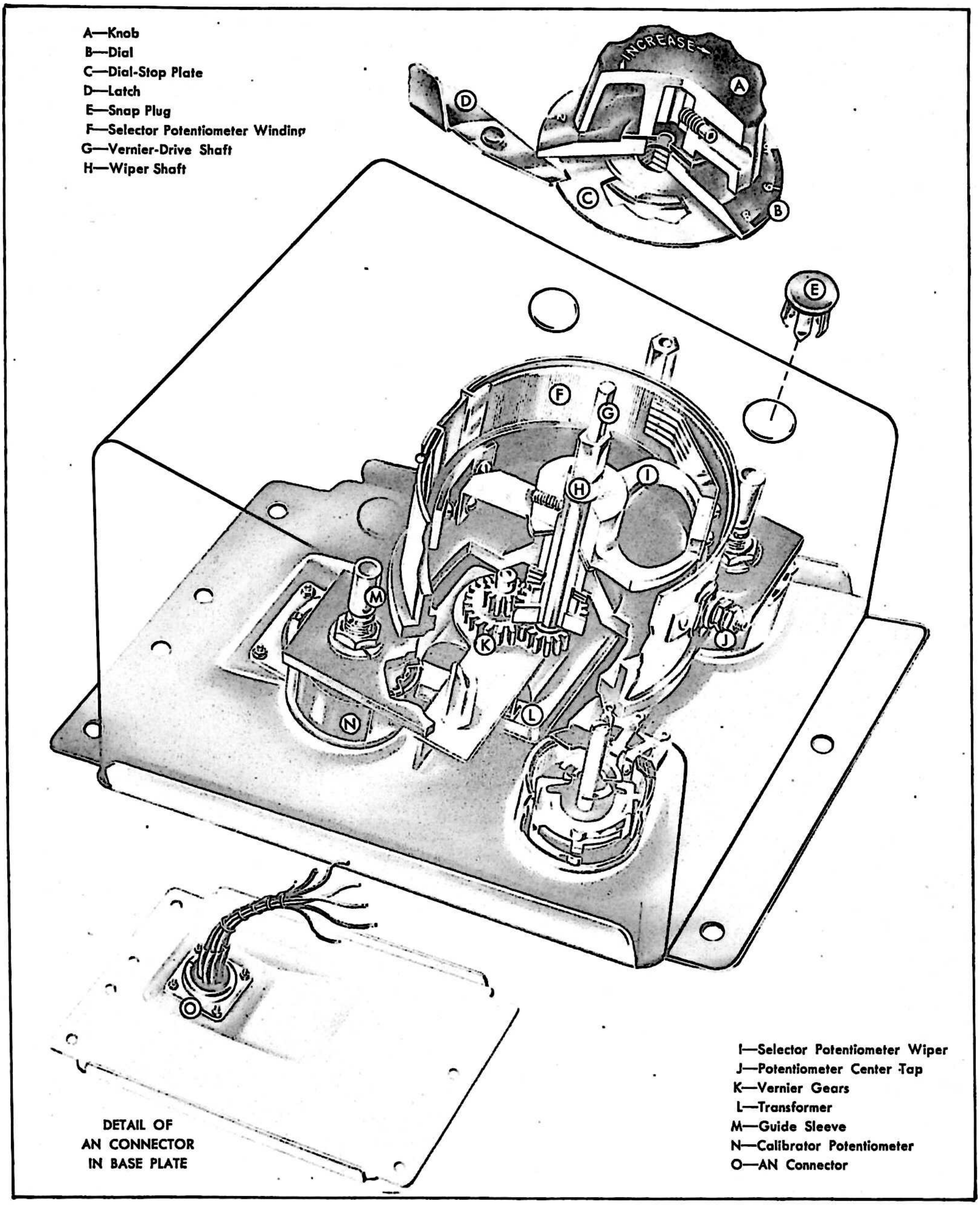


Figure 17—Cutaway View of Turbo-Boost Selector

drive shaft by a setscrew, while the dial fits over the square end of the wiper shaft.

(*c*) CALIBRATOR POTENTIOMETERS.—Four calibrator potentiometers (N) are arranged around and below the selector potentiometer. Each is connected to the control system for the corresponding engine. The calibrator for engine No. 1 is at the upper left, for engine No. 2 at lower left, for No. 3 at lower right, and for No. 4 at upper right. These potentiometers transmit the electrical signal from the selector potentiometer to the four control systems (on multi-engined airplanes). By varying the signal sent to each system, they provide a means of compensating for small variations in engine characteristics.

These calibrators are adjustable from the exterior of the unit. Removing the snap plugs (E) exposes the screwdriver adjustment and guide sleeve (M) for each calibrator.

(*d*) MODEL VARIATIONS.—On early model G1056A1CA1 and -A2CA1 units, 15 volts was impressed on each calibrator potentiometer, while on Model G1056A1CA2 and -A2CA2 units, nine volts is used. This voltage is supplied by tapping a section of the secondary winding on the transformer.

When these units are factory installed in a special case, as in B-17 airplanes, or without cases, as in B-29 airplanes, the reference arrow may be found in a different location with respect to the front of the unit. The calibrator adjustment for each engine will then be found in a correspondingly different position.

The turbo-boost selector was previously marked "MANIFOLD PRESSURE SELECTOR," and also was made with different printing on the top surface. (See figure 18.) In some models the reference arrow is above the dial. These changes in appearance and nomenclature were made for easier understanding and use of the turbo-boost selector. They in no way affect the operation of the unit, and do not require correction or modification in the field.

(2) INTERNAL WIRING. (See figure 19.)—The turbo-boost selector transformer (L), located under the selector potentiometer, supplies 30 volts which is impressed on the potentiometer winding. This winding is center-tapped (J), and the tap is connected to a center tap on the transformer, to provide more uniform voltage distribution across the winding.

The four calibrator potentiometers are connected in parallel and are supplied by tapping the transformer secondary to provide either nine or fifteen volts, depending on the model. (See paragraph (*d*) preceding.) The internal connections of the turbo-boost selector are shown in figure 19.

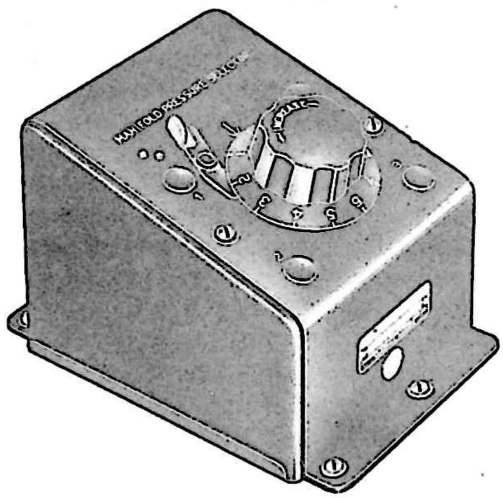


Figure 18—"Manifold-Pressure Selector," Early Model

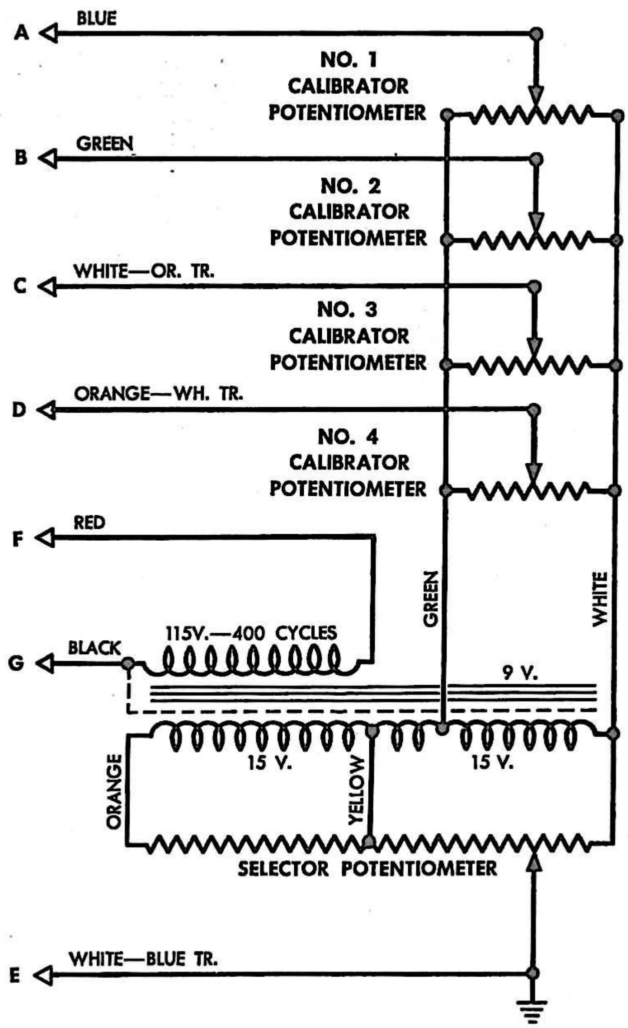


Figure 19—Internal Wiring of Turbo-Boost Selector

(3) SPECIFICATIONS.

(*a*) GENERAL.

Type number	
With case, threaded shaft	G1056A1
With case, flat shaft	G1056A3
Without case, threaded shaft	G1056A2
Without case, flat shaft	G1056A4
AN receptacle	AN 3102-16S-1P
Weight	2 pounds

(*b*) POTENTIOMETERS.

Resistance of selector potentiometer	1000 ohms ± 5%
Resistance of each calibrator potentiometer	200 ohms ± 10%
Input voltage to transformer	115 volts, 400 cycles
Voltage impressed on selector potentiometer	30 volts
Voltage impressed on calibrator potentiometers:	
Model G1056A1CA1	15 volts
Model G1056A2CA1	15 volts
Model G1056A1CA2	9 volts
Model G1056A2CA2	9 volts
Model G1056A3CA2	9 volts
Model G1056A4CA2	9 volts
Tension of selector potentiometer wiper fingers	20 grams minimum
Maximum rotation of calibrators	270 degrees

b. INDUCTION-SYSTEM PRESSURETROL.—The induction-system Pressuretrol (figure 20) is the primary sensing device of the turbo control system. It is actuated by pressure variations at the carburetor inlet. It consists of a voltage-dividing potentiometer operated by a pair of bellows connected to the induction system near the carburetor inlet. (See figure 21.)

(1) DETAILS OF CONSTRUCTION.

(*a*) HOUSING AND EXTERIOR.—The Pressuretrol is housed in a cast aluminum case, with a flat cover of the same material held on by 12 cover screws. Both case and cover have a black crackle finish. Three tapped mounting holes in the sides of the casting provide a means for attaching the Pressuretrol to its mounting brackets.

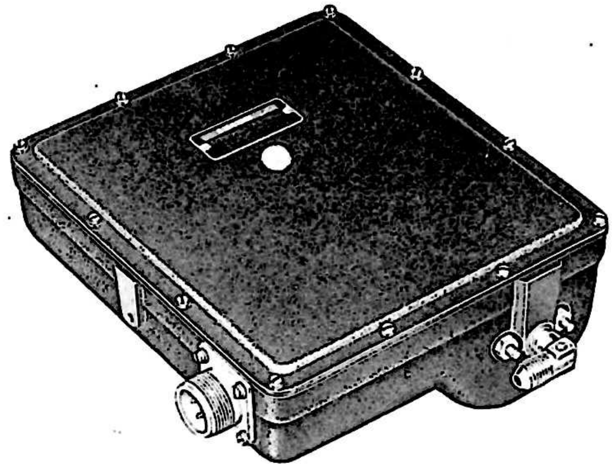


Figure 20—Pressuretrol, Exterior View

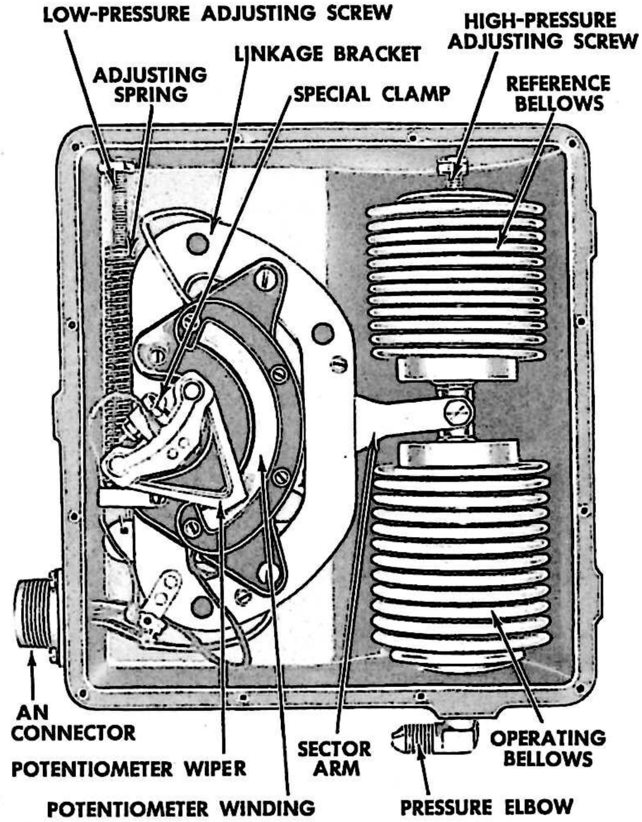


Figure 21—Pressuretrol, Interior View

The unit is connected to the pressure source through a 90-degree brass elbow screwed into the bottom of the case. A small hole at the bottom of the case permits drainage and ventilation. Electrical connections to the unit are made through a three-prong AN-connector receptacle at the side of the case. Two adjusting screws at the top provide a means of adjusting the pressure range of the unit.

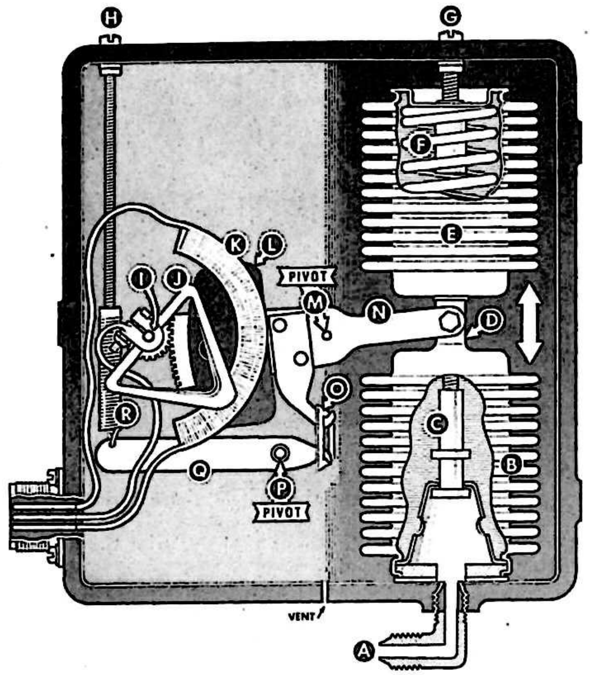


Figure 22—Schematic Drawing of the Pressuretrol

(*b*) BELLOWS ASSEMBLY.—Two bellows are used in the Pressuretrol: the operating bellows and the reference bellows. Together they move the potentiometer wiper by means of the sector arm and pinion gear. (See figure 22.)

The operating bellows (B) is bolted to the bottom of the case, and carburetor-inlet pressure is piped to its interior through the elbow (A). A gasket prevents leakage at the bottom of the bellows. An adjustable internal stop (C) prevents excessive collapse or expansion which would drive the wiper off the end of the potentiometer winding.

The reference bellows (E) is rigidly connected to the operating bellows by a cross-member (D), to which is attached the sector arm. The upper end of the reference bellows is attached to the case by an adjustment screw (G).

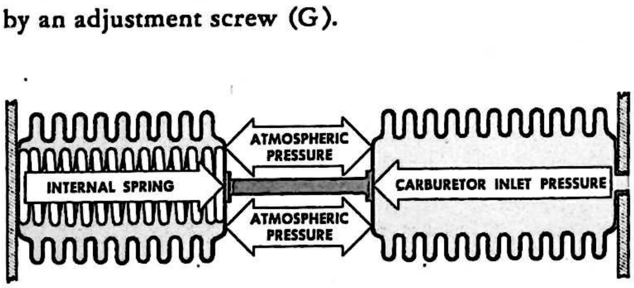


Figure 23—Diagram Showing Forces Which Act on Bellows Assembly

(*c*) FUNCTION OF THE REFERENCE BELLOWS.—The purpose of the reference bellows is to enable the Pressuretrol to maintain desired absolute pressures under varying atmospheric temperature and pressure conditions. It has the same cross-sectional area as the operating bellows, and therefore atmospheric pressure changes will affect both equally. Since the operating bellows and reference bellows are arranged to oppose each other, the atmospheric pressure change is canceled out.

To eliminate interior pressure variations due to temperature changes, the air has been pumped out of this bellows. An internal compression spring (F), which is not appreciably affected by temperature changes, takes the place of internal air pressure to prevent collapse.

The balance of forces acting on the two bellows is shown in figure 23. Two forces are impressed on the operating bellows: internal pressure, which is carburetor inlet pressure; and external or atmospheric pressure. The two forces operating on the reference bellows are the internal spring tension and atmospheric pressure. Since the bellows oppose each other, atmospheric pressure cancels out. Therefore, it may be seen that carburetor inlet pressure is constantly opposed only by the spring tension. (An adjusting spring, R, is added for calibration purposes only. See paragraph (*f*) following.) This allows pressure control in terms of absolute pressure, regardless of altitude or climate.

(*d*) SECTOR ARM AND LINKAGE. (See figure 22.)— The sector arm (N) translates the straight-line motion of the bellows assembly into a rotary motion to move the wiper across the potentiometer winding. The sector arm turns on a pivot (M) which is held by the linkage bracket (not shown). One end is pivoted on the bellows cross-member (D), and the other end has a gear sector cut into it which meshes with a pinion on the potentiometer wiper shaft (I). The laminated steel counterbalance (L) prevents erratic movement of the sector arm due to the vibration of the airplane. The sector arm is connected to the adjusting spring (R) by means of the adjusting spring link (O).

(*e*) POTENTIOMETER ASSEMBLY.—The Pressuretrol potentiometer (K) is part of the electrical control circuit. Movement of the potentiometer wiper produces a signal calling for proper movement of the waste gate, depending on whether carburetor inlet pressure increases or decreases.

As it is installed in the unit, the upper end of the potentiometer winding is the "low-pressure" end. When carburetor air pressure drops, the operating bellows collapses and the potentiometer wiper (J) is moved by the sector arm and gears toward the top of the potentiometer winding, producing an electrical signal which calls for a closed waste gate. When pressure increases, the opposite is true. (The potentiometer is calibrated for a maximum pressure variation of 16 to 34 inches Hg.) Voltage across the potentiometer is supplied by one secondary of a transformer located in the nacelle junction box. (See paragraph *g* following.)

The potentiometer winding is fastened to the linkage bracket by four screws. The wiper is held firmly on the wiper shaft (I) by a double clamp held tight by a special bolt and locking nut. An anti-backlash spring around the shaft takes up play in the linkage so the wiper always operates directly against the pressure of the operating bellows. It also acts as a safety feature to drive the wiper to the bottom of the potentiometer winding in case the sector gear and pinion become disengaged.

(*f*) ADJUSTMENTS.—Two calibration adjustment screws at the top of the case are provided for adjusting the pressure range through which the Pressuretrol operates. These are painted red and marked "CALIBRATION SCREWS—DO NOT TAMPER," and should not be adjusted in the field. The high-pressure adjustment screw (G) raises or lowers the top of the reference bellows to vary the reference pressure against which the operating bellows must act. This has the effect of establishing the pressure required to move the wiper to the high-pressure end of the winding. The low-pressure adjustment screw (H) varies the tension of the adjusting spring (R) against which the sector arm and wiper mechanism must act as the operating bellows contracts because of a decrease in carburetor inlet pressure. Thus, adjustment screw (H) regulates the amount of pressure drop required to move the wiper to the low-pressure end of its winding. The tension of the adjusting spring is transmitted to the sector arm through the adjusting spring lever (Q) and link (O). The adjusting spring lever turns around pivot (P).

The travel limits of the sector arm can be varied up or down by the adjustable internal stop (C) in the operating bellows. This adjustment, as well as the calibration adjustments, is set at the factory and should not be changed in the field.

(2) INTERNAL WIRING.—The internal wiring of the Pressuretrol is completely explained by the internal wiring diagram (figure 24).

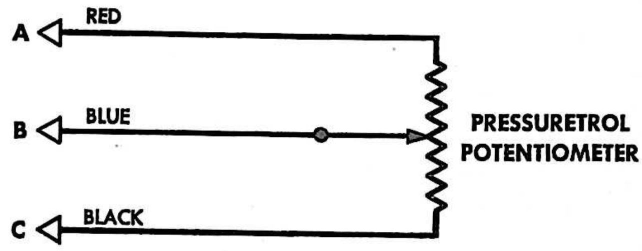


Figure 24—Internal Wiring of Pressuretrol

(3) SPECIFICATIONS.

(*a*) GENERAL.

Type number	G16A
AN receptacle	AN 3102-14S-1P
Weight	3 pounds 14 ounces
Pressure range	16 to 34 inches Hg

(*b*) POTENTIOMETER.

Resistance of potentiometer	= 800 ohms (+20%, −8%)
Voltage across potentiometer	30 volts
Wiper tension	7 to 12½ grams
Wiper mounting	1/64 inch below top of shaft

c. TURBO GOVERNOR.—The turbo governor (figure 25) consists of two separate mechanisms, each of which performs a safety control function. The accelerometer prevents overshooting of manifold pressure during sudden pressure increases, yet allows very rapid acceleration of the turbo. The overspeed mechanism automatically limits the turbine wheel in the supercharger to a safe top speed. Both mechanisms are

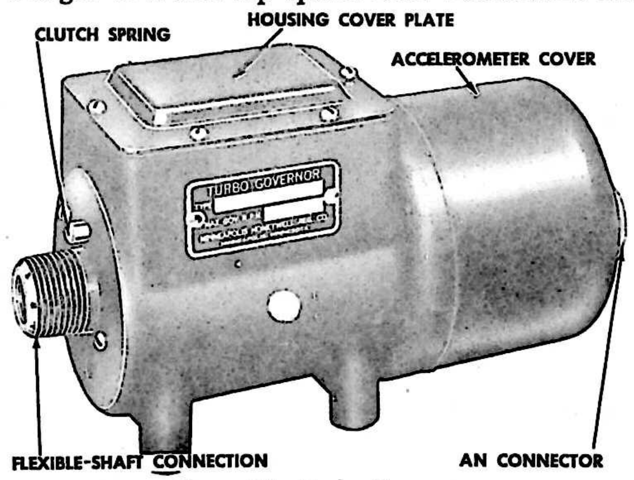


Figure 25—Turbo Governor

1—Housing Cover Plate
2—Clutch Gear
3—Counterclockwise Drive Gear
4—Clutch Disc
5—Clockwise Drive Gear
6—Clutch-Disc Shaft
7—Clutch Spring
8—Threaded Connector
9—Splined Governor Shaft
10—Clutch-Lever Adjusting Screw
11—Thrust Collar
12—Mounting Bracket
13—Clutch-Lever Pivot
14—Clutch Lever
15—Flyball Weight
16—Governor Spring
17—Spring Barrel
18—Inertia Rotor
19—Torque Spring
20—Locking Plate
21—Cam Plate
22—Guide
23—Cam-Roller Assembly
24—Potentiometer Wiper
25—Push Rod
26—Crosshead
27—Wiper Arm
28—Frame Assembly
29—Potentiometer Winding
30—An Connector
31—Accelerometer Cover
32—Return Spring
33—Fulcrum Adjustment
34—Wiper-Arm Pivot
35—Terminal Block
36—Nut on Governor Shaft
37—Bearing Plate
38—Governor Shaft
39—Governor Housing
40—Declutching Extension Arm
41—Potentiometer Winding
42—Collector Bar
43—Lead Screw
44—Potentiometer Wiper
45—Lead-Screw Nut
46—Lead-Screw Drive Gear

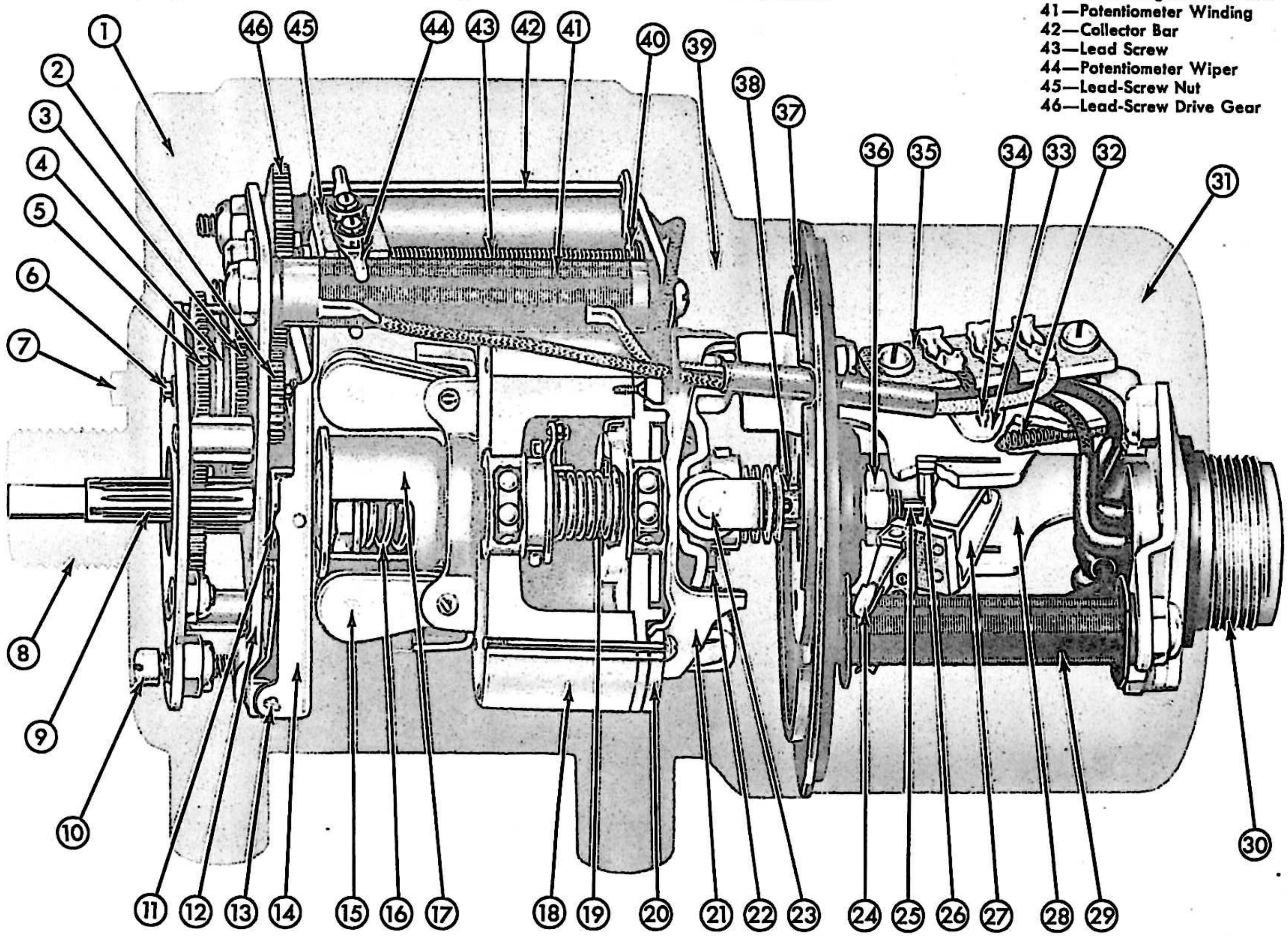


Figure 26—Phantom View of Turbo Governor

operated by a single shaft in the governor, which is driven by a flexible drive from the turbo tachometer connection. (Refer to paragraph *d* following for a complete description of the flexible drive.) The turbo governor is driven at a speed proportional to the speed of the turbosupercharger by a gear reduction in the turbo, which is different in different types of superchargers. The internal construction of the governor is shown in figure 26.

On early models of the governor, a special locking spring (figure 27) is used to lock the flexible drive to the housing.

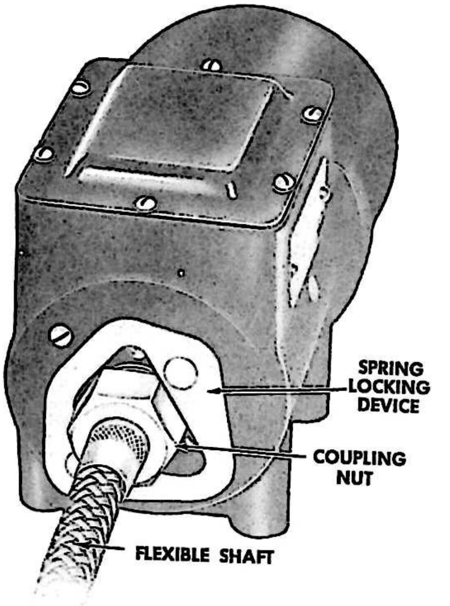


Figure 27—Locking Device Used on Early Model Governors

(1) ACCELEROMETER. (See figure 26.)—The accelerometer section of the governor is located under the cup-shaped accelerometer cover, and is operated by the inertia rotor, located in the governor housing. This heavy rotor is free to turn on the rotor shaft, but is coupled to the shaft through a torque spring. When the shaft is rotating at a uniform rate, the rotor also rotates at the same rate in a fixed position with respect to the shaft. However, whenever the shaft accelerates, the inertia of the rotor causes it to lag behind the shaft, flexing the torque spring. The lag of the rotor is translated into straight-line motion by a cam-and-roller mechanism which moves the wiper across the potentiometer winding and produces an electrical signal opposed to the signal which produced the acceleration. The accelerometer signal tends to open the waste gate slightly as manifold pressure approaches the value called for. This prevents overshooting manifold pressure, yet allows rapid acceleration of the turbo.

As acceleration is reduced, the torque spring brings the rotor back to its original position with respect to the shaft, and the wiper is returned to its rest position.

(*a*) CAM-AND-ROLLER MECHANISM.—The cam-and-roller mechanism consists of a cylindrical cam plate with inclines cut into it, and a cam-roller assembly containing rollers which ride on the inclines or cam surfaces. (For purposes of illustration, figure 28 shows only two rollers and inclines. The actual unit has three, as shown in figure 26.)

The cam plate is held rigidly on the rotor by a locking plate. The cam-roller assembly is keyed to the rotor shaft by means of the push-rod actuating crosshead and the cam-roller-assembly guide, which prevent the roller assembly from turning on the shaft, but allow it to slide freely along the slotted portion of the shaft.

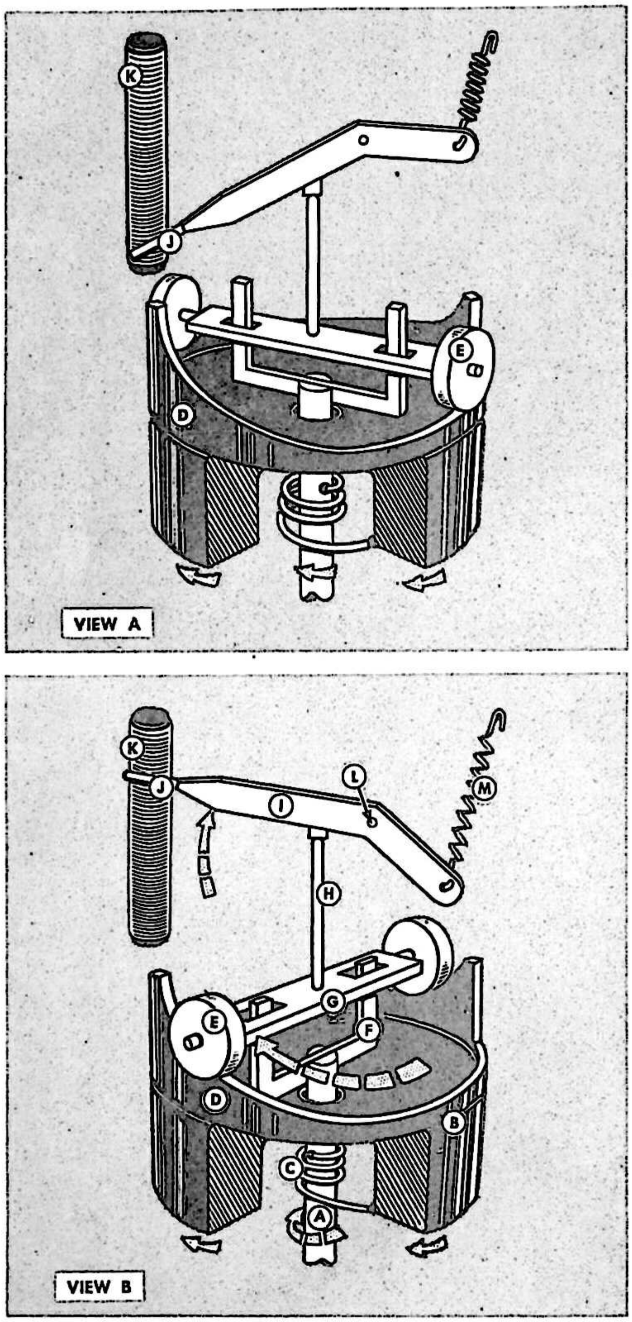
The rotor shaft is hollow above its slotted portion and contains a double-pointed push rod which seats in a depression in the push-rod-actuating crosshead. When the crosshead moves along the shaft, the push rod is also moved. The other end of the push rod seats in a potentiometer-wiper-actuating crosshead which slides in slots in the frame assembly.

(*b*) POTENTIOMETER ASSEMBLY.—The potentiometer-wiper arm rests on the wiper-actuating crosshead, and is pivoted in the frame assembly.

The potentiometer wiper is made with two contact fingers which contact the potentiometer winding on opposite sides. This double contact minimizes the possibility of plane vibration breaking the contact between the wiper and the winding. A large fiber washer on each end of the winding prevents the wiper from moving beyond it. A small electrical dead spot, formed by soldering several turns together, is provided at the end of the winding nearest the bearing plate. Its purpose is to prevent minute fluctuations of the wiper from affecting the operation of the system.

A terminal block located on the frame assembly provides a connection for wiring from the overspeed section of the governor. The seven-prong AN-connector receptacle is mounted permanently on the frame assembly.

(*c*) OPERATION. (See figure 28.)—The cam rollers (E) normally rest on the flat portions of the



A—Governor Shaft	G—Crosshead
B—Inertia Rotor	H—Push Rod
C—Torque Spring	I—Wiper Arm
D—Cam Plate	J—Potentiometer Wiper
E—Cam Roller	K—Potentiometer Winding
F—Guide	L—Wiper-Arm Pivot
M—Return Spring	

Figure 28—Schematic Drawings of Accelerometer Operation. View A, Normal Position of Accelerometer Parts. View B, Position of Parts During Excessive Acceleration

inclines cut into the cam plate (D). (See view A.) The potentiometer wiper (J) rests at the bottom of its winding (K), and no electrical signal is sent by this portion of the governor.

When acceleration occurs (view B), the rotor (B) lags momentarily behind rotation of the shaft (A), and the cam surfaces are turned with respect to the rollers. The rollers are forced to ride along the cam surfaces and up the inclined sections of the surfaces. This moves the roller assembly and crosshead (G) along the shaft, displacing the push rod (H).

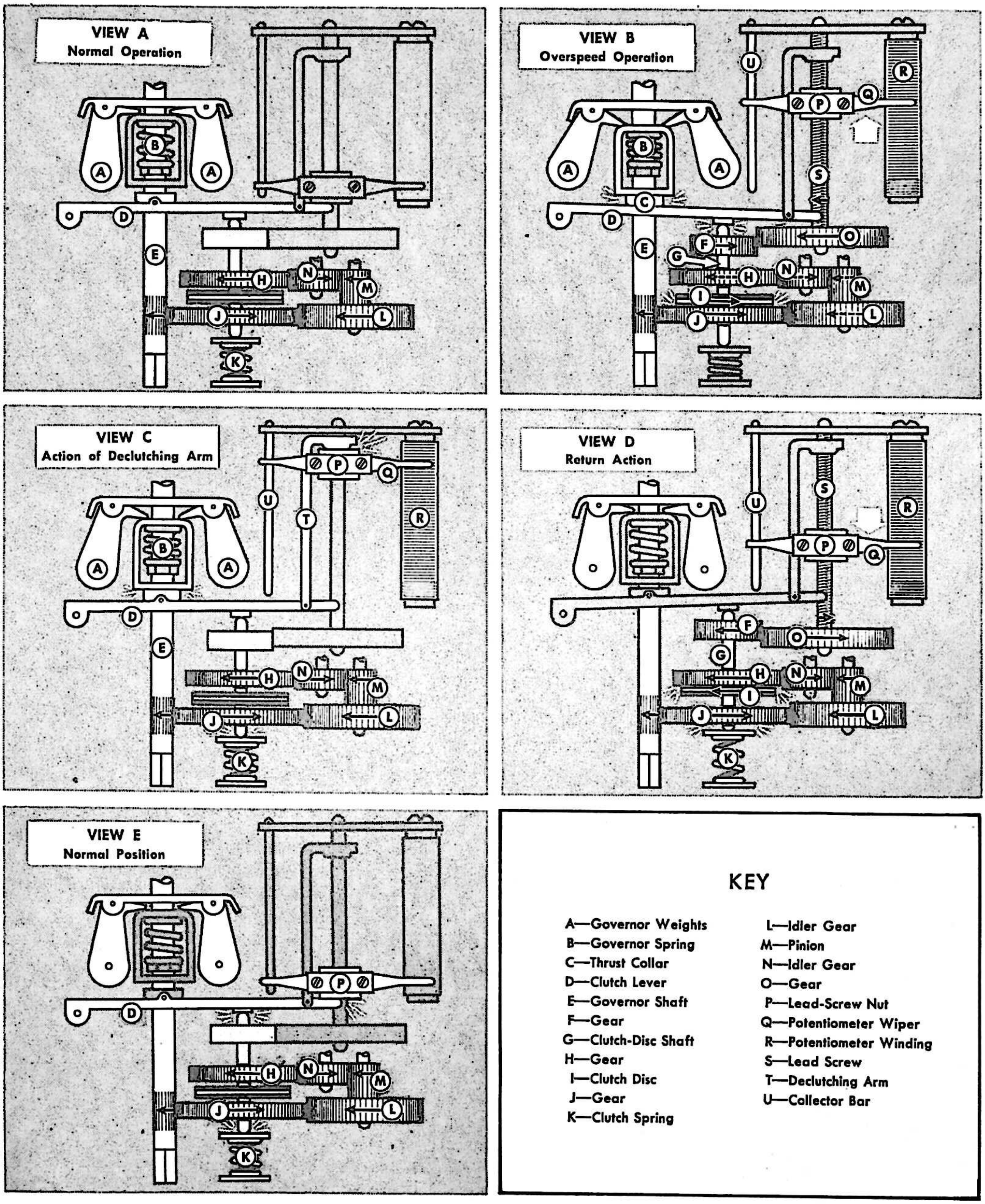
The push rod acts on the wiper arm (I), moving the wiper across its winding. This produces a signal calling for the waste gate to open slightly and prevent overshooting of manifold pressure.

When the rotor shaft is no longer accelerating, the cam rollers move down their inclines to their normal positions, and the wiper is returned to the bottom of the winding by the wiper-arm return spring The rest position of the wiper may be changed by a fulcrum adjustment which moves the wiper-arm pivot.

(2) OVERSPEED. (See figure 29.)—The overspeed section is located within the governor housing, under the housing cover plate. Its operating parts consist of a gear train, a flyball governor, a clutch, and a driving mechanism which moves the potentiometer wiper. The gear train and flyball governor are constantly driven by the rotor shaft.

(*a*) POTENTIOMETER WIPER ASSEMBLY. —The double potentiometer wiper (Q) is mounted on the threaded lead-screw nut (P), which is moved by the lead screw (S). The cylindrical potentiometer winding is contacted by the two wipers, one on each side. A collector rod on the opposite side of the assembly is also contacted by two collector wipers.

(*b*) NORMAL-SPEED OPERATION. (See view A, figure 29.)—The turbo-governor shaft (E) drives the gear train consisting of gears J, L, M, N, and H, as well as the flyball governor, made up of the two flyball weights (A). All these parts rotate constantly when the governor shaft is rotated. Note that all these gears rotate freely on their shafts, and gears H and J rotate in opposite directions. Between the two gears is a clutch disc (I) which is rigidly attached to the clutch-disc shaft (G). The clutch lever (D) bears against the top of the shaft, and the clutch spring (K) bears against the bottom end of the shaft. Other parts of the assembly (shaded in view A) are normally not in operation.



KEY

A—Governor Weights
B—Governor Spring
C—Thrust Collar
D—Clutch Lever
E—Governor Shaft
F—Gear
G—Clutch-Disc Shaft
H—Gear
I—Clutch Disc
J—Gear
K—Clutch Spring
L—Idler Gear
M—Pinion
N—Idler Gear
O—Gear
P—Lead-Screw Nut
Q—Potentiometer Wiper
R—Potentiometer Winding
S—Lead Screw
T—Declutching Arm
U—Collector Bar

Figure 29—Schematic Illustration of Overspeed Operation

(*c*) OVERSPEED OPERATION. (See view B, figure 29.)—When the governor shaft (E) rotates at an excessive speed, the flyball weights (A) are thrown outward by centrifugal force, compressing the governor spring (B) and forcing the spring barrel against the clutch lever (D). The clutch lever presses against the end of the clutch-disc shaft, forcing the clutch disc against gear J. This causes the clutch-disc shaft and the attached gear (F) to rotate, driving the lead screw (S) by means of the lead-screw drive gear (O). Rotation of the lead screw causes the potentiometer wiper (P), threaded to the screw, to move out on the potentiometer winding (R). The resulting electrical signal causes the waste gate to open and slow down the turbosupercharger.

As the turbosupercharger begins to slow down, pressure of the spring barrel against the clutch lever is diminished, and the clutch spring (K) moves the clutch disc upward until it no longer engages gear J. This will stop rotation of the clutch disc, and the potentiometer wiper will remain where it is on the potentiometer winding.

However, if the potentiometer wiper should happen to travel to the end of the lead screw before the turbosupercharger has slowed down sufficiently to disengage the clutch, the wiper will strike the declutching extension arm (T). (Refer to view C.) The declutching extension arm (not found on all models) is connected to the clutch lever in such a way that pressure of the wiper on this arm lifts the clutch lever against the force applied by the governor. This action has the same effect as slowing down the turbosupercharger because the clutch spring will then disengage the clutch by forcing the clutch disc away from gear J.

(*d*) DECELERATION. (See view D, figure 29.)—When the turbosupercharger has decelerated to a speed at which the flyball governor no longer applies force to the clutch lever, the clutch spring forces the clutch disc upward against gear H, which causes the clutch disc and its attached gear F to rotate in the opposite direction. This causes opposite rotation of the lead-screw drive gear, resulting in downward movement of the potentiometer wiper.

As the potentiometer wiper reaches the bottom of the potentiometer winding (see view E) it strikes the extension fingers of the clutch lever, forcing the lever downward against the clutch-disc shaft. This action disengages the clutch disc from gear H and returns the entire mechanism to its normal-speed position.

The clutch-lever adjustment screw which moves the pivot point of the clutch lever is set at the factory to cause the overspeed governor to come into operation at a given maximum turbo speed. It is painted red and should not be adjusted in the field.

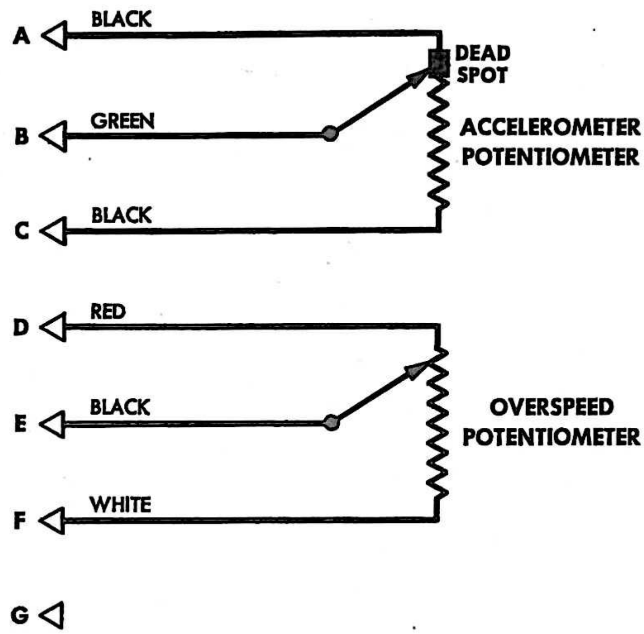


Figure 30—Internal Wiring of Governor

(3) INTERNAL WIRING.—The internal wiring of the turbo governor is completely shown in the wiring diagram (figure 30). Thirty volts impressed on the accelerometer potentiometer is obtained from one secondary of the transformer in the nacelle junction box. (See section II, paragraph 2 *g*.) Twenty-four volts impressed on the overspeed potentiometer is obtained by tapping another secondary of the same transformer.

(4) SPECIFICATIONS.

(*a*) GENERAL.

Type number	G1057A
AN receptacle	AN 3102-16S-1P
Weight	2 pounds 13 ounces

(*b*) ACCELEROMETER SECTION.

Resistance of potentiometer	700 ohms, ± 20%
Wiper tension	11 ± 2 grams
Position of wiper	1/32 ± 1/64 inch below active winding
Position of cam rollers	on flat, 1/32 inch from ramp

(*c*) OVERSPEED SECTION.

Resistance of potentiometer	750 ohms, ± 20%
Wiper tension	15 ± 5 grams
Wiper travel time (shaft at 2240 rpm)	
To overspeed end	7½ seconds
Return to normal position	30 seconds
Maximum speed	
Model G1057A1CA2	2530 rpm
Model G1057A2CA2	2240 rpm
Model G1057A3CA2	2460 rpm
Model G1057A4CA2	2780 rpm
Model G1057A5CA2	2733 rpm

(Models ending in -CA1 have identical ratings, but are without the declutching arm.)

d. FLEXIBLE DRIVE. (See figure 31.)

(1) DETAILS OF CONSTRUCTION.—A flexible drive is provided for connecting the governor to the turbo tachometer drive. This flexible connection is necessary because the governor can seldom be mounted directly in line with the turbo tachometer drive.

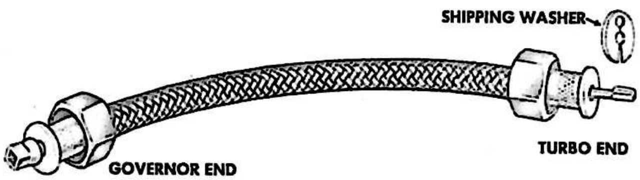


Figure 31—Flexible Drive Shaft

The flexible drive consists of an internal shaft within a braided housing. It is available in two lengths: a 10-inch length for B-17 and B-29 airplanes, and a 5½-inch length for B-24 airplanes.

One end contains a square socket, which fits over the rotor shaft of the governor. A coupling nut screws onto the ⅞-inch, 18-thread connector on the governor housing. The other end of the shaft fits the turbo tachometer drive. A coupling nut holds it securely.

Flexible drives are shipped with a split washer on the turbo end, to keep the internal shaft from sliding out during shipment. This washer is removed and discarded at the time of installation. (See section III, paragraph 2 *d* (2).

(2) SPECIFICATIONS.

Type number	G1057A1CA1
Length	
Model G1075A1CA1	5½ inches
Model G1075A2CA1	10 inches
Weight	
5½-inch shaft	4 ounces
10-inch shaft	7 ounces

e. AMPLIFIER.—The amplifier supplies power to operate the waste gate in response to signals received from the other control units of the system. It contains a fuse for the system, a power transformer, resistors and condensers, and four vacuum tubes.

(1) DETAILS OF CONSTRUCTION.

(*a*) HOUSING AND EXTERIOR.—The amplifier parts are mounted on an aluminum chassis which is housed in a rectangular case with a black crackle finish. (See figure 32.) The amplifier chassis slides into the case on two horizontal guide rails (M), and is easily removed by means of a handle (A) on the front.

The chassis is locked into the case by a Dzus fastener at the rear. The AN connector (K), mounted on the chassis, protrudes through the rear of the case. Another Dzus fastener (L) below the front of the case locks it into the tray, which is mounted on Lord shock mounts (O). Louvers (N) on the top of the case and holes punched in the bottom and sides provide ventilation to cool the interior.

(*b*) POWER TRANSFORMER.—The 115-volt supply from the airplane's rotary inverter is brought to the amplifier power transformer through a 1-ampere fuse (H) mounted on the chassis. This fuse also protects all other parts of the control system except the primary winding of the transformer in the turbo-boost selector.

The transformer (G), also mounted on the chassis, has three secondary windings. One supplies plate current for the 7C5 tubes to energize the amplifier winding of the waste-gate motor (see paragraph *f*, following). The second supplies plate current for the rectifier tube (7Y4), and the third supplies heater current for all tubes.

(*c*) TUBES.—The amplifier is operated by four tubes—one 7Y4 rectifier (D), one 7F7 duo-triode (E) used as a voltage amplifier, and two 7C5 beam power amplifiers (B) used as discriminators. The 7F7 amplifies the signal from the electrical control system, while the 7C5's discriminate between a signal calling for open waste gate and one calling for closed waste gate. The 7C5 plate current operates the waste-gate motor. The 7Y4 supplies a d-c plate voltage for the 7F7 tube.

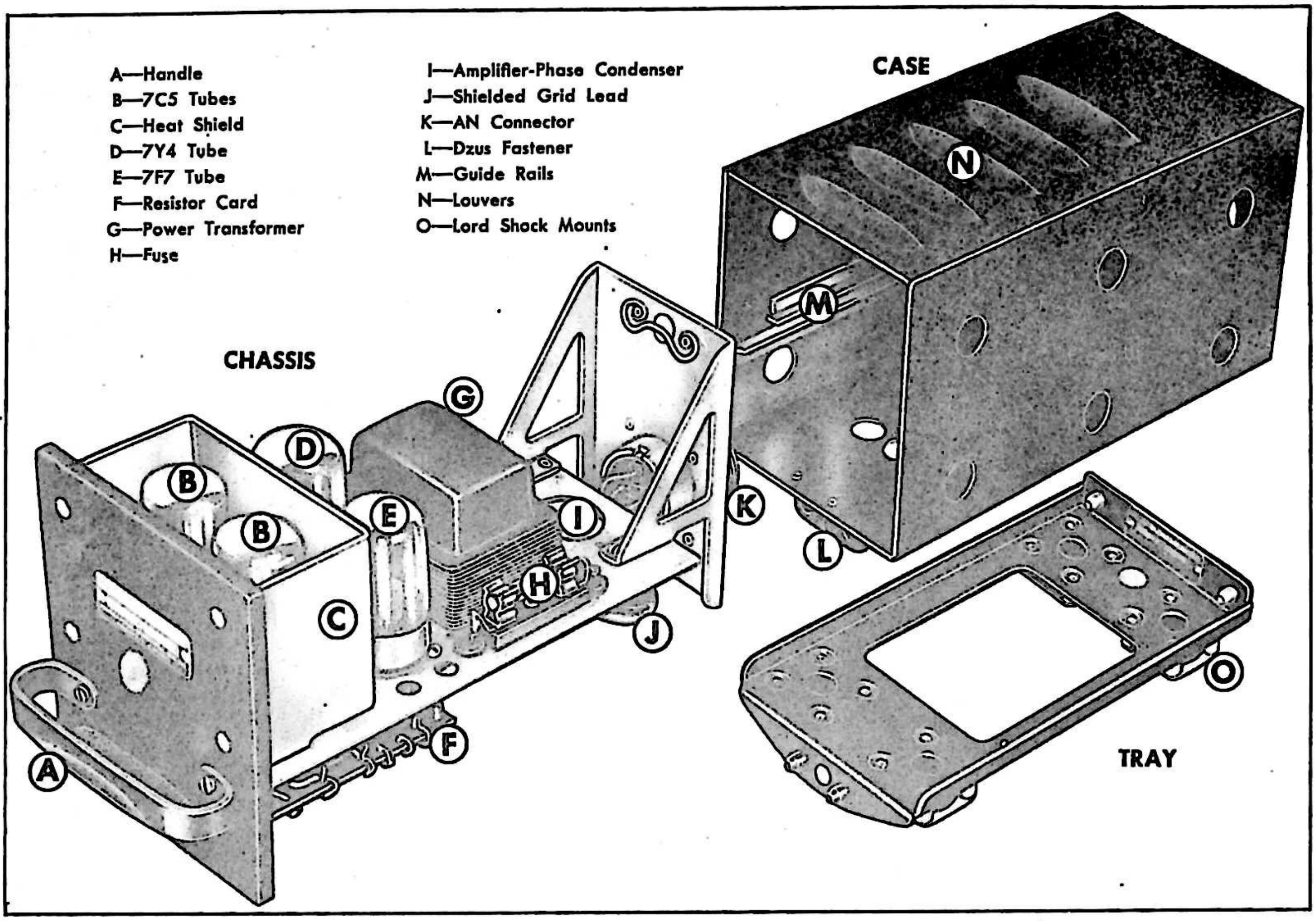


Figure 32—Turbo Control System Amplifier

A heat shield (C) around the 7C5's acts as a flue to guide cooling air around them and also shields the rest of the amplifier from their heat. The 7C5's operate at a much higher temperature than do the other tubes.

(*d*) CONDENSERS AND RESISTORS.—Filter condensers and resistors are mounted on two cards (F) on the under side of the chassis beneath the tubes. There are six 1-megohm resistors and one 30,000-ohm resistor on the bottom of the cards, and two .05-, three .01-, and one .001-microfarad condensers on the tops of the cards. (On Model G403ACA3 amplifier, one 1-megohm resistor is replaced by a 150,000-ohm resistor. (See paragraph (*e*) following.)

The .2-microfarad condenser (I) mounted under the rear of the chassis is connected in parallel with the amplifier-excited winding of the waste-gate motor. (See paragraph *f*.) It is actually made up of two .1-microfarad condensers in one case, connected in parallel.

(*e*) MODEL VARIATIONS. (See wiring diagram, figure 33.)—On early Model G403A1CA1 amplifiers, the voltage supply to the rectifier tube (7Y4) was 360 volts, and the resistor (R) in the plate voltage supply to the second stage of the 7F7 tube had a value of 1 megohm. In the Model G403A1CA2 amplifier, this voltage was reduced to 250 volts; the resistance remained the same. In the Model G403A1CA3 unit, the voltage is 250 volts, but the resistance is reduced to 150,000 ohms.

These changes were made to increase tube life and provide better motor response to signals from the control circuit. Electrical characteristics of Model G403A1CA11 are identical with those of G403A1CA3.

(2) FUNCTION OF THE AMPLIFIER.—The amplifier receives electrical signals from the control units of the system and amplifies these signals to cause operation of the waste-gate motor by energizing one of the motor windings. (See paragraph *f*(1)(*b*) following.)

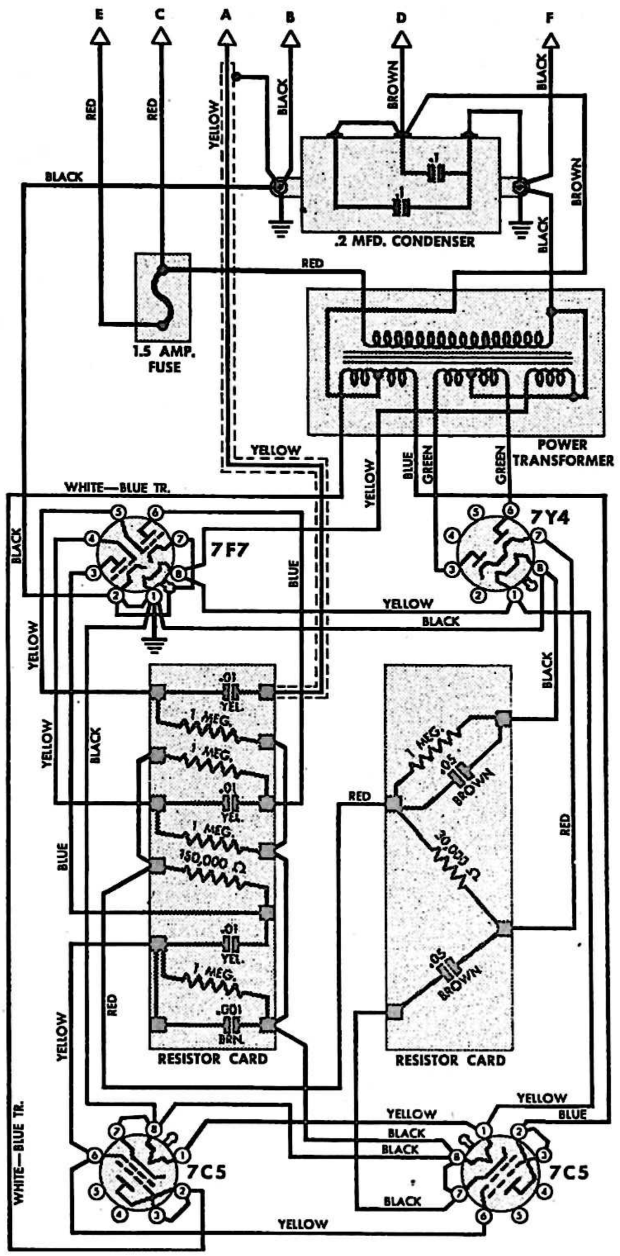


Figure 33—Internal Wiring of Amplifier

The current provided by the amplifier to operate the motor will be either in phase with the line current or 180 degrees out of phase. The phase of this output current, which is the same as the phase of the incoming signal, controls the direction of rotation of the waste-gate motor.

For a more complete explanation of amplifier operation, see section IV, paragraph 1 *d*.

(3) INTERNAL WIRING.—The internal connections of the amplifier are completely shown in figure 33. This shows the location of all wiring and parts of the amplifier.

The signal from the control system is brought into the amplifier through a shielded yellow wire (J, figure 32) running along the bottom of the chassis. The wire connects to one .01-microfarad condenser, and its shielding is grounded to the chassis.

The wire to AN prong "D" is the output to the waste-gate motor.

(4) SPECIFICATIONS.

(*a*) GENERAL.

Type number	
Amplifier	G403A1
Tray	G1060A1CA1
AN receptacle	AN 3102-22-24P
Weight (including mounting tray)	3 pounds 8 ounces

(*b*) ELECTRICAL

Input voltage	115 volts, 400 cycles
Transformer output	
Heater voltage	6.75 volts
Plate voltage	400 volts
Rectifier voltage	
Model G403ACA1	360 volts
Model G403ACA2, -CA3, -CA11	250 volts
Fuse	1 ampere
Tubes	Two 7C5's, one 7Y4, one 7F7

f. WASTE-GATE MOTOR.—The waste-gate motor (figure 34) is the operating unit which moves the turbo waste gate in response to signals from the control units of the system. It is a two-phase a-c motor, which transmits power to a crank arm through a train of speed-reduction gears.

The crank arm is connected to the waste gate of the turbosupercharger by a mechanical linkage. (This linkage is furnished by the airplane manufacturer and is provided in various lengths to fit specific types of airplanes.)

(1) DETAILS OF CONSTRUCTION.—The waste-gate motor has a black crackle finish. It is made up of a gear housing which encloses the gear train and balancing-potentiometer assembly, a cup-shaped motor housing, and an AN connector mounted on the gear housing. The housings and connector are cast aluminum. The steel crank arm is mounted externally on the gear housing, on the end opposite the stator housing.

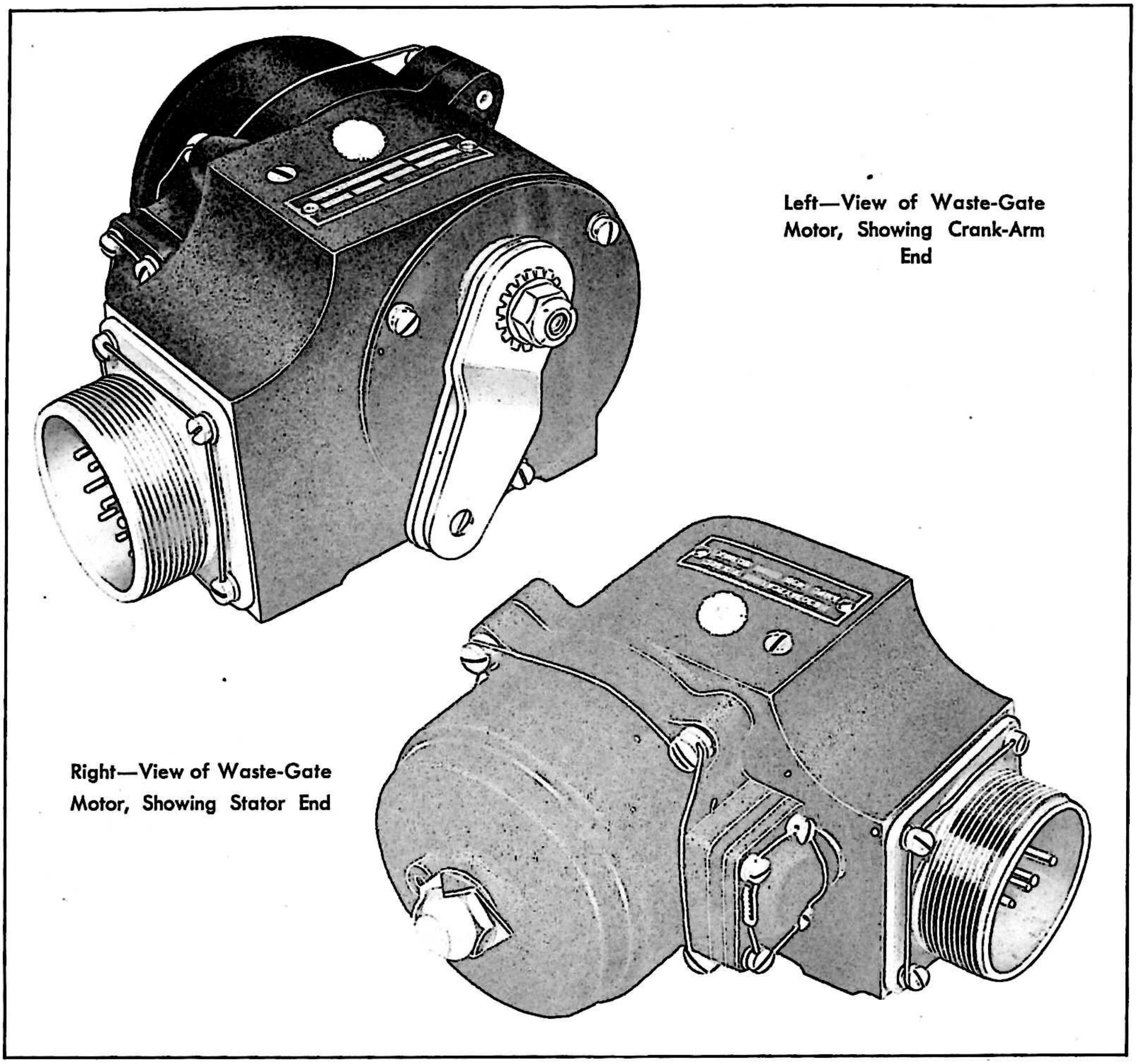
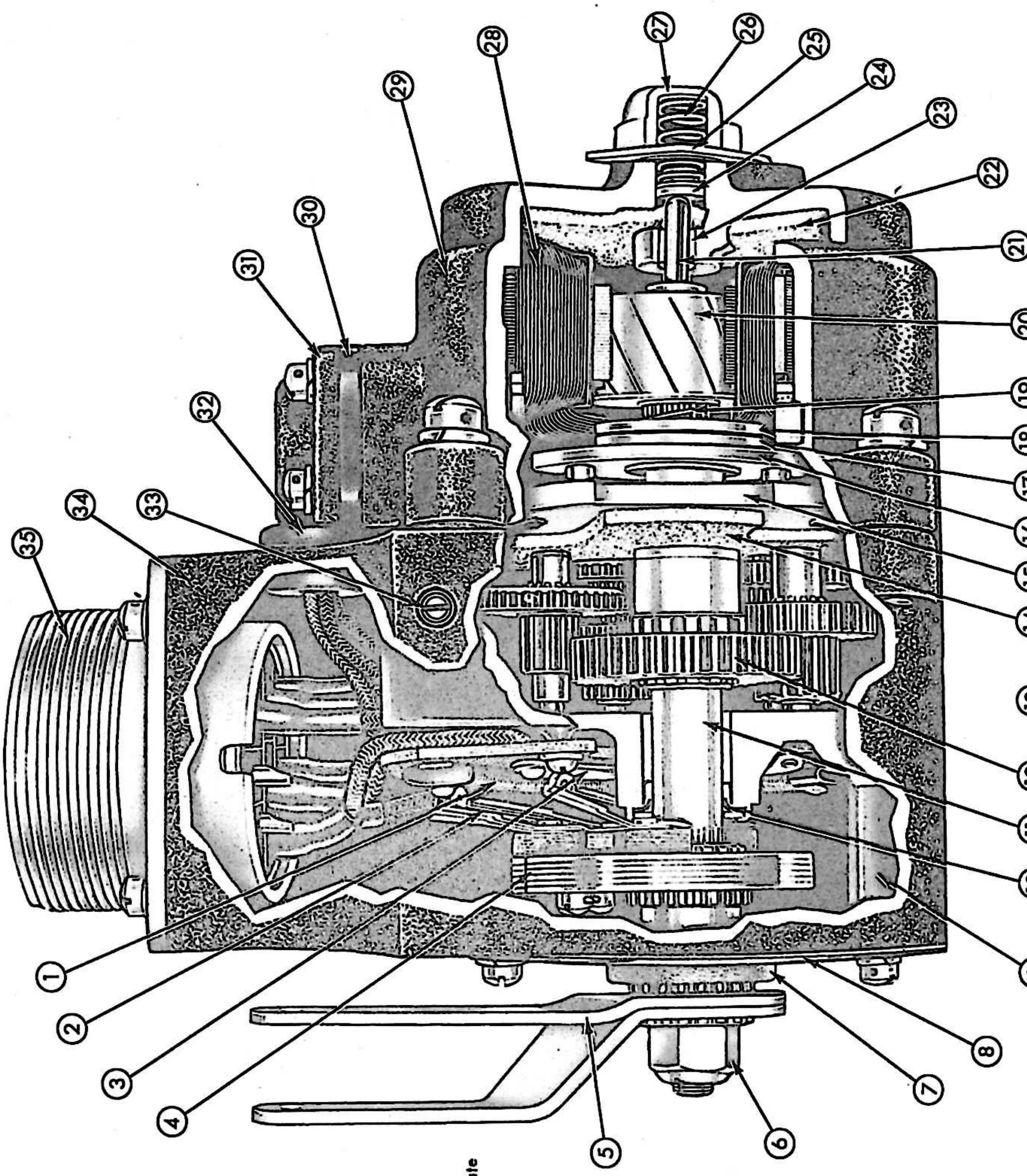


Figure 34—Waste-Gate Motor

(*a*) TWO-PHASE MOTOR CONSTRUCTION.—The unit is powered by a two-phase, reversible, induction-type motor which is contained in the stator housing. It consists of a stator assembly and an armature assembly. (See figure 35.)

1. The stator assembly consists of eight pole pieces, each of which is wound with a coil of wire. The coil leads are brought into the housing through a terminal block (30) which seals the exterior against oil leakage. Alternate coils are connected in series, four coils forming the fixed or line-excited winding, and four coils forming the amplifier-excited winding. If these coils were numbered in rotation, coils 1, 3, 5, and 7 would form one winding, and coils 2, 4, 6, and 8 would form the other. Either set of coils may be used as the line-excited winding, depending on the desired direction of rotation of the motor. Energizing these two windings operates the waste-gate motor when movement of the waste gate is called for by one of the control units.

2. The armature assembly is made up of the armature (20), the armature shaft (21), brake and



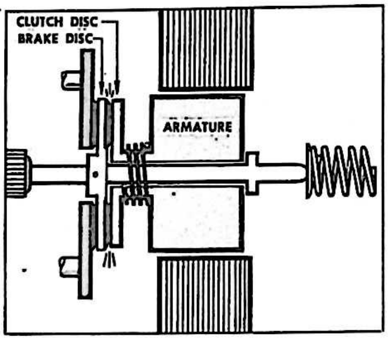
1—Potentiometer Winding
2—Potentiometer Wiper
3—Collector Strip
4—Stop Plate
5—Crank Arm
6—Castellated Nut
7—Dust Washer
8—Cover Plate
9—Mechanical Stop
10—Neoprene Oil Seal
11—Output Shaft
12—Bull Gear
13—Gear Train
14—Felt Oiler
15—Armature-Assembly Mounting Plate
16—Brake Plate
17—Brake Disc
18—Clutch Disc
19—Clutch Spring
20—Armature
21—Armature Shaft
22—Felt Oiler
23—Sleeve Bearing
24—Thrust Plug
25—Brake Spring Lock Washer
26—Brake Spring
27—Brake Spring Cap
28—Stator Coil
29—Stator Housing
30—Terminal Block
31—Terminal Block Cover
32—Rubber Grommet
33—Oil Plug
34—Gear Housing
35—AN Connector

Figure 35—Cutaway View of Waste-Gate Motor

clutch mechanism, and the armature assembly mounting plate (15). The armature is of laminated steel with one brass lamination at each end. It is connected to the armature shaft by means of the clutch mechanism. The armature shaft drives the gear train (13), and through it the crank arm (5), by means of a drive pinion pressed onto the end of the armature shaft.

3. CLUTCH AND BRAKE MECHANISM.—The clutch and brake mechanisms are located together at the drive end of the armature assembly. The clutch is a safety device which prevents damage to the gear train when the potentiometer wiper assembly (2 and 4) strikes a mechanical stop. The brake stops shaft rotation whenever the amplifier-phase winding ceases to be energized.

a. CLUTCH OPERATION.—The armature is not directly connected to its shaft, but drives the shaft through the clutch mechanism, which consists



When Armature Shaft Is Stopped Suddenly, Armature Is Allowed to Rotate for a Short Time by Slippage Between Clutch Disc and Brake Disc

Figure 36—Schematic Drawing of Clutch Operation

of a clutch disc and the clutching surface of the brake disc. (See figure 36.) The clutch disc slides horizontally along a sleeve attached to the armature and is keyed to it. The clutch disc bears against the top of the brake disc (17), which is rigidly connected to the shaft. A clutch spring (19) between the armature and the sliding clutch disc exerts constant tension to keep the clutch engaged. During normal motor operation the armature drives the shaft with no slippage. However, when the wiper assembly strikes the mechanical stop at either end of its travel, clutch slippage allows the rotor to turn for a short time around its shaft. Without the clutch, armature inertia would place a strain on the gear train which might damage the bakelite gears.

b. BRAKE OPERATION.—The braking surfaces consist of a cork disc and a brake disc. (See figure 37.) The cork disc is inserted in the rigidly

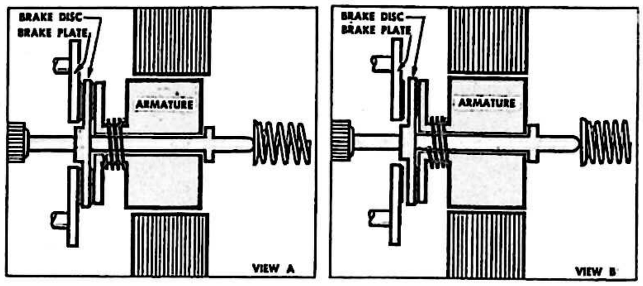


Figure 37—Schematic Drawing of Brake Operation. View A: Motor Stopped, Brake Surfaces Engaged. View B: Motor Running, Brake Surfaces Disengaged

mounted brake plate (16). The steel brake disc (17) is part of the armature shaft, which has approximately 1/32-inch end play with respect to the stator. A brake spring (26) under the cap (27) acts on the end of the shaft, holding the brake disc against the cork surface when the motor is not in operation. The armature is then out of alignment with the pole faces.

When the amplifier-phase winding is energized, magnetic attraction on the armature pulls the shaft lengthwise, bringing the armature into alignment with the pole faces. This disengages the braking surfaces and allows the shaft to rotate.

When the amplifier-phase winding ceases to be energized, the magnetic pull is decreased. The brake spring then displaces the armature shaft to re-engage the braking surfaces. The braking effect is greatly magnified through the gear train, so that the magnitude of the external force required to slip the brake is considerably above any such force occurring in operation.

(*b*) TWO-PHASE MOTOR OPERATION.—Like any two-phase motor, this unit is caused to operate by current flowing through the two field windings, the current in one winding being 90 degrees out of phase with the current in the other. One phase winding—the line-excited or fixed phase—is energized by the airplane's rotary inverter through a condenser.

The other field winding is energized by the amplifier when an electrical signal is sent to the amplifier by one of the turbo control units. The current in the amplifier phase will lead or lag the line-excited phase by 90 degrees (see paragraph *e* (2), preceding), depending on whether the signal sent to the amplifier called for the waste gate to open or close. When the current in the amplifier-phase winding of the motor leads the line-excited phase, rotation of the waste-gate motor will be in one direction. When it lags, rotation will be in the opposite direction. This

two-phase current will operate the waste-gate motor as long as a signal is being received by the amplifier, or until the potentiometer wiper assembly strikes a mechanical stop.

(*c*) GEAR-TRAIN ASSEMBLY.—The gear-train assembly is located in the gear housing and provides a speed reduction of 1689:1. (See figure 38.) It transmits motor rotation to the crank arm through the bull-gear-and-output-shaft assembly.

The gear train is made up of six gear-and-pinion assemblies, mounted on five bearing shafts. One end of each of these shafts is pressed into the gear housing, and the other ends fit into holes in the armature-assembly mounting plate. The six gear-and-pinion assemblies are driven by the drive pinion on the armature shaft.

The gear housing contains a quantity of oil which allows the lowest gears to run in oil and lubricate the other gears. A felt disc against the armature-assembly mounting plate lubricates the drive pinion, gear-train shafts, and bull-gear end of the output shaft. This oil also lubricates the rear armature-shaft bearing. It seeps into the stator housing, and a felt disc at the rear of the housing carries oil to the bearing. An oil plug (33, figure 35) is provided for draining or refilling the gear case with oil.

A neoprene seal around the output shaft keeps oil from leaking out of the lubricated portion of the housing. Any attempt to remove the output shaft without a special tool will damage this seal. It should never be removed in the field, since all maintenance relating to the gears is Fourth Echelon work.

(*d*) POTENTIOMETER ASSEMBLY. (See figure 39.)—The potentiometer, located under the cover plate in the gear housing, is the balancing potentiometer of the electrical control circuit. The potentiometer assembly, consisting of a semi-circular winding (1, figure 35) and a collector strip (3), is held in place by three mounting screws.

The stop-plate-and-wiper assembly (2 and 4) is splined onto the output shaft (11), and moves with the crank arm. The wiper (2) contacts both the winding and the collector strip. Mechanical stops in the gear housing (34) limit the rotation of the crank arm to 90 degrees (see paragraph (*f*) following), and the stop plate is constructed so as to absorb the shock of striking the stops.

(*e*) CRANK ARM AND LINKAGE. (See figure 35.)—The crank arm (5) is a double steel arm to which the waste-gate linkage is attached. The crank

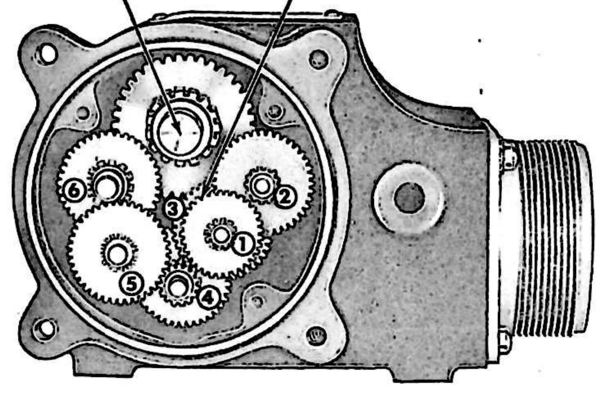


Figure 38—View of Gear Train in Waste-Gate Motor

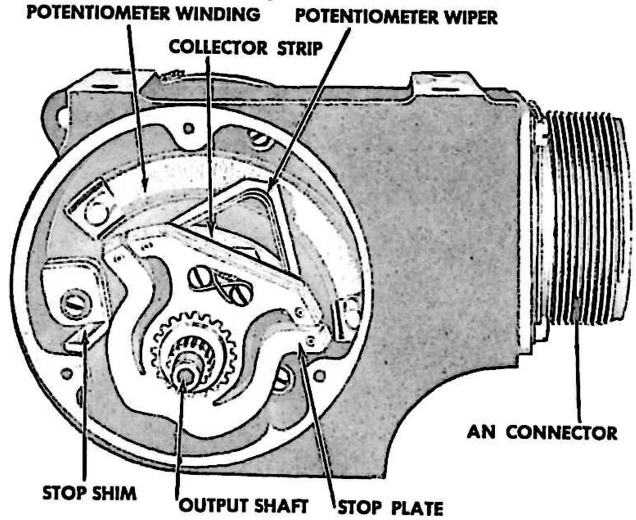


Figure 39—View of Balancing Potentiometer in Waste-Gate Motor (Stop Shim Is Not Used in G303AY2CA2 Motors)

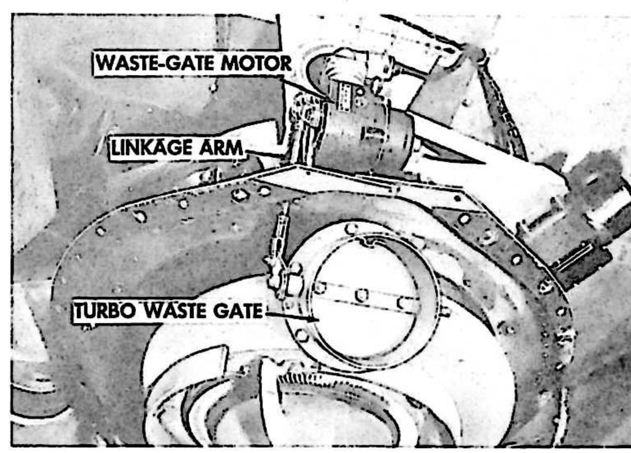


Figure 40—Waste-Gate Motor and Linkage on B-24 Turbosupercharger

arm fits over the splined output shaft, and is tightened on the shaft by a nut (6). It is adjustable in steps of 22½ degrees, permitting the crank arm to be placed in the most advantageous position relative to the waste-gate arm. (See figure 40.)

(*f*) MODEL VARIATIONS.—Model G303A1CA1 is identical to the above description with the exception of the crank arm, which is a single steel arm.

Model G303AY2CA1 has the mechanical stops cast as part of the housing. This has been modified by the addition of a stop shim which slightly shortens the travel of the stop-plate-and-wiper assembly, so that variations in castings cannot cause a travel of more than 90 angular degrees. The modified unit is known as Model G303AY2CA11. In the Model -CA2 motor, this shim is unnecessary, as the casting has been changed to compensate for the thickness of the shim.

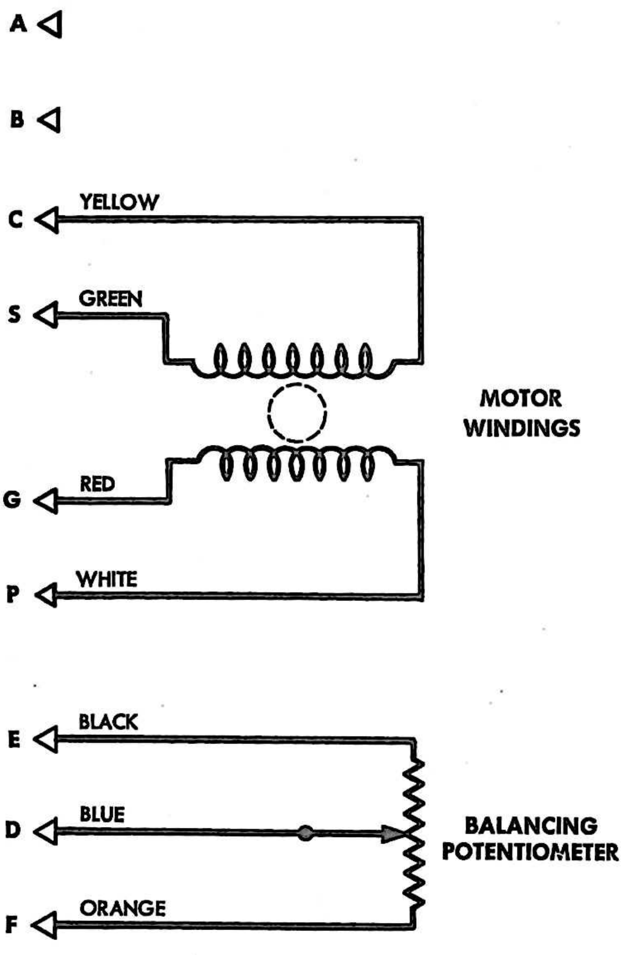


Figure 41—Internal Wiring of Waste-Gate Motor

(2) INTERNAL WIRING.—The internal wiring of the waste-gate motor is completely shown in the wiring diagram (figure 41). Twelve volts impressed on the potentiometer is supplied by one of the secondary windings on the transformer in the nacelle junction box. (See section II, paragraph 2 *g*.)

(3) SPECIFICATIONS.

(*a*) GENERAL.

Type number	G303AY2
AN receptacle	AN 3102-28-4P
Weight	2 pounds 14 ounces
Degrees of crank-arm travel	90 degrees maximum
Time for full travel	2.2 to 2.4 seconds
Gear reduction ratio	1689:1
Lubricating oil	Indoil No. 7

(*b*) BALANCING POTENTIOMETER.

Resistance	925 ohms ± 13%
Impressed voltage	12 volts
Wiper tension	15 to 35 grams

(*c*) TWO-PHASE MOTOR.

Resistance of each winding	50 ohms
Applied voltage	115 volts, 400 cycles
Developed voltage in windings (with 30-millivolt signal in amplifier)	
Fixed phase	325 volts (+75 volts, −10 volts)
Amplifier phase	200 volts (+25 volts, −10 volts)
Maximum armature speed	12,000 rpm
Rated torque	50 pound-inches
Torque to slip clutch	2.1 to 3.0 ounce-inches

g. NACELLE JUNCTION BOX.—The nacelle junction box, or "J" box (figure 42), located within the engine nacelle, provides a means of interconnecting the Pressuretrol, governor, waste-gate-motor leads, and the main "J" box.

(1) DETAILS OF CONSTRUCTION. (See figure 43.)—Two terminal blocks within the unit have ten terminals each. The blocks are identified by the letters A and B stamped on metal tabs attached to the blocks. The terminals are identified by numbers from 1 to 10 on the bakelite dividers adjacent to each terminal post.

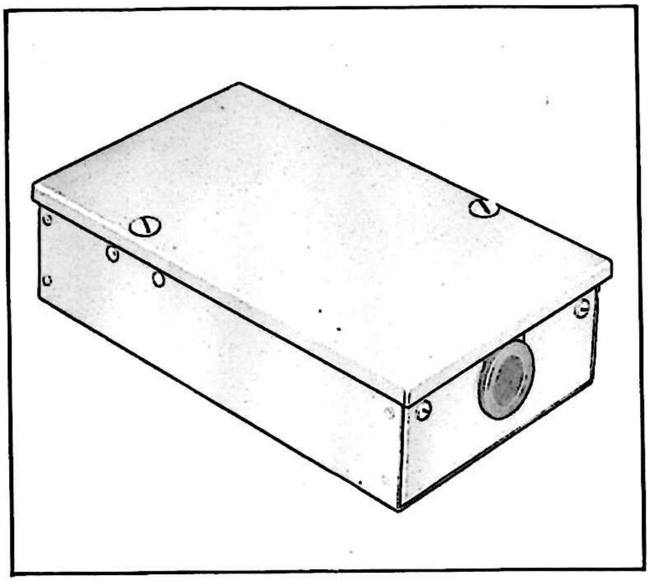


Figure 42—Nacelle "J" Box

The nacelle "J" box is also a convenient place for locating a transformer (B), a condenser (A), and three resistors employed in the control circuit. The transformer is wound with two secondaries. The 30-volt secondary supplies the voltage for the Pressuretrol and accelerometer potentiometer. The other secondary supplies a total of 42 volts, of which 12 volts is applied to the waste-gate-motor balancing potentiometer, and 24 volts to the overspeed potentiometer. The 6-volt portion, between the 12- and 24-volt sections, is not impressed on any potentiometer, but is used to balance the control system electrically so that the calibrator potentiometer wiper will be near the center of its winding during normal operation.

Two .1-microfarad condensers, in parallel with each other and assembled in one case to form a .2-microfarad unit (A), are connected in series with the line-excited winding of the waste-gate motor.

Two 50,000-ohm resistors are mounted on a card (C) between the upper ends of the two terminal blocks. These are the protective resistors of the system, and cause the waste gate to open if the contact is broken between any wiper and its potentiometer winding.

Another resistor of 500 ohms is on a card (D) fastened to terminals A8 and A10. It is connected between one end of the accelerometer potentiometer winding and its wiper, and prevents an open circuit in case vibration causes intermittent wiper contact.

A hole with rubber grommet (F) is provided on one end of the unit for bringing in external wires.

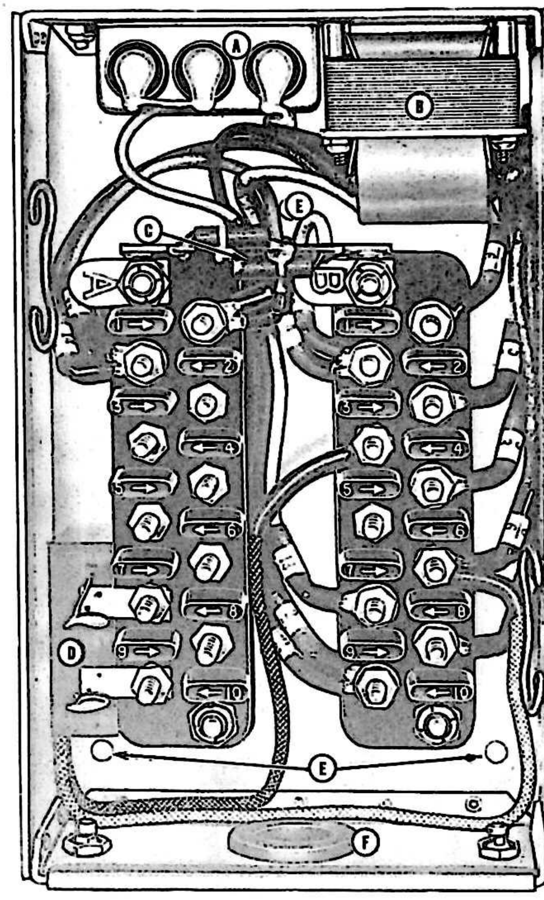


Figure 43—Interior of Nacelle "J" Box

There are three mounting holes (E) in the bottom of the box. The cover is held in place by two Dzus fasteners.

(2) INTERNAL WIRING.—Sixteen wires leading to the transformer, condensers, and resistors within the unit make up the internal wiring. These connections are completely shown in figure 44. (For connection diagram of all leads brought into the nacelle "J" box from other units, see figure 130)

(3) SPECIFICATIONS.

Type number	G1065A1CA1
Weight	1 pound 9 ounces
Resistors	50,000 ohms ± 20%
	50,000 ohms ± 20%
	500 ohms ± 10%
Condenser	0.2 microfarad
Transformer secondaries	30 volts
	42 volts, with taps producing 6, 12, and 24 volts

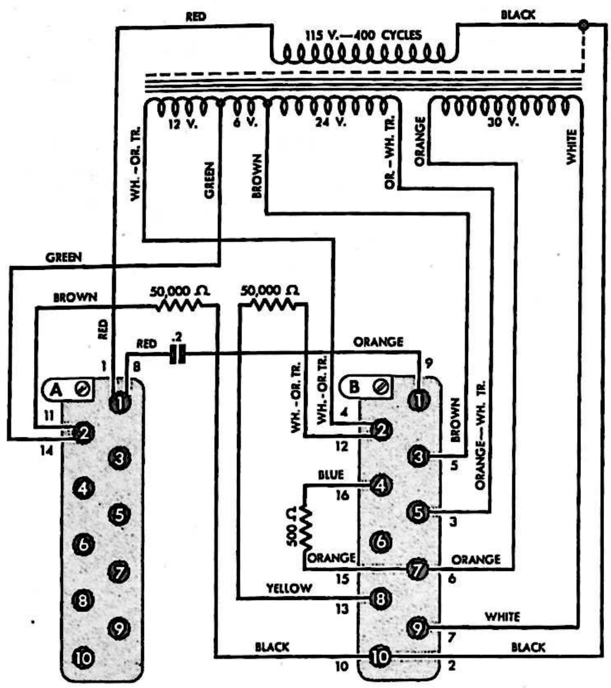


Figure 44—Internal Wiring of Nacelle "J" Box

b. MAIN JUNCTION BOX. (See figure 45.)—The main junction box, or "J" box, is used for interconnection of the various component units of the system.

(1) DETAILS OF CONSTRUCTION.—The main "J" box consists of an aluminum box containing three terminal blocks of ten terminals each. (See figure 46.) The blocks are marked A, B, and C by identification tabs. The terminals are identified by numbers from 1 to 10 on the bakelite dividers adjacent to each terminal post. Terminals B1, B2, B3, and B4 are connected together at the block by metal links. Terminals B7 and B8, as well as B9 and B10, are also connected by metal links.

The aluminum cover is held on by two Dzus fasteners. An envelope fastened to the inside of the cover (figure 47) contains a wiring diagram of the system, a troubleshooting procedure, and a diagram of all wiring connections within the "J" box.

Three wiring holes in one side of the box are provided with rubber grommets. Four mounting holes in the bottom allow the unit to be bolted to the airplane.

(2) INTERNAL WIRING.—There are no leads connected to main "J" box terminals before installation in the complete system. For a complete diagram of all leads brought into the "J" box from other units, see figure 129.

(3) SPECIFICATIONS.

Type number	G1066A1CA1
Weight	1 pound 6 ounces

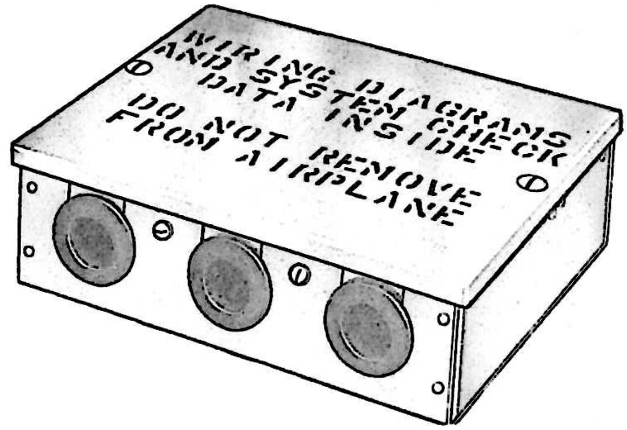


Figure 45—Main "J" Box

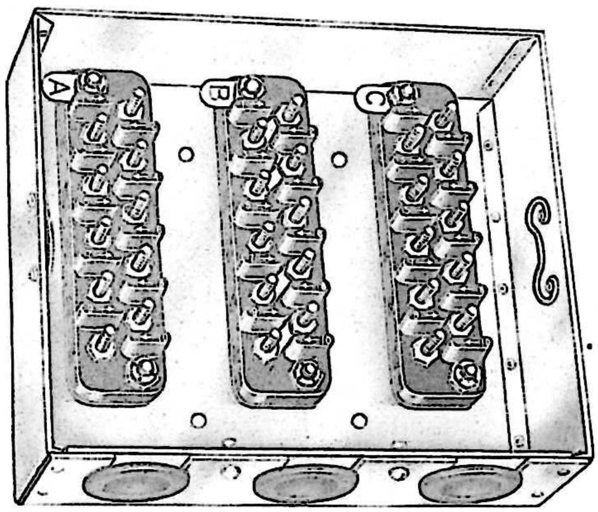


Figure 46—Interior of Main "J" Box

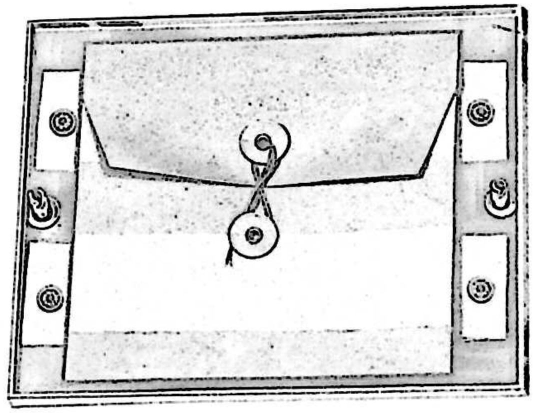
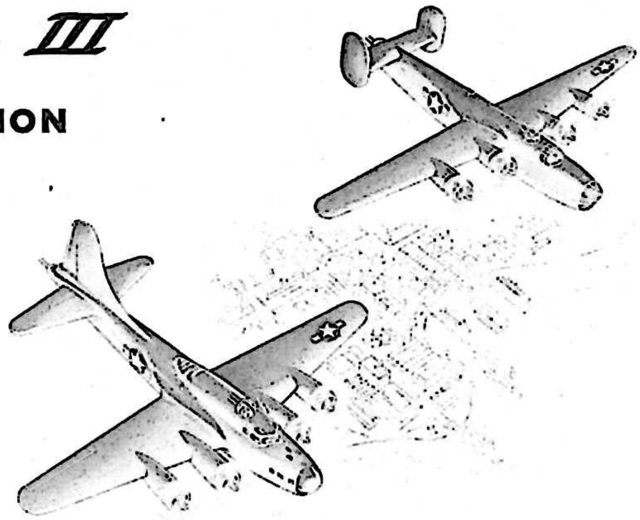


Figure 47—Envelope Inside Main "J" Box Cover

Section III

INSTALLATION



1. GENERAL.

a. The following instructions on the installation of the type B control system for turbosuperchargers include the general method used for installing individual units in the various types of airplanes. Installations made at the factory may differ slightly from installations made at modification centers, but in general the instructions given here apply to all airplanes of a particular type.

b. Figure 93 is a layout diagram of a complete turbo control system installation in a B-17 airplane. For a similar diagram showing the installation in a B-24, refer to figure 2.

c. After any unit in the turbo control system or component part of the power plant has been installed or replaced, the control system must be inspected, recalibrated when necessary, and its operation checked, as outlined in paragraphs 4, 5, and 6 of this section.

d. For instructions on removal of turbo control system units, refer to section V, paragraph 3.

2. INSTALLATION OF INDIVIDUAL UNITS.

a. TURBO-BOOST SELECTOR.

(1) LOCATION.

(*a*) B-17 AIRPLANES AND B-24 AIRPLANES.—The turbo-boost selector is conveniently located on the control pedestal. In modification installations, the turbo-boost selector, with its case, is mounted on top of the control pedestal. (See figure 48.) On B-17 factory installations, however, the turbo-boost selector is fitted part way into the pedestal and has a special cover in place of its regular case. (See figure 16.)

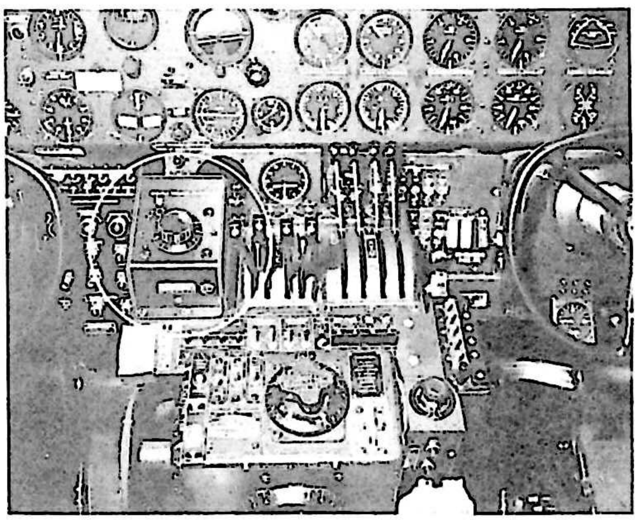


Figure 48—Location of Turbo-Boost Selector, B-24 Airplanes

(*b*) B-29 AIRPLANES.—In the B-29 airplane, the entire mechanism of the turbo-boost selector is enclosed within the pedestal, and only the dial, the knob, and the dial stop are visible above the pedestal. (See figure 49.)

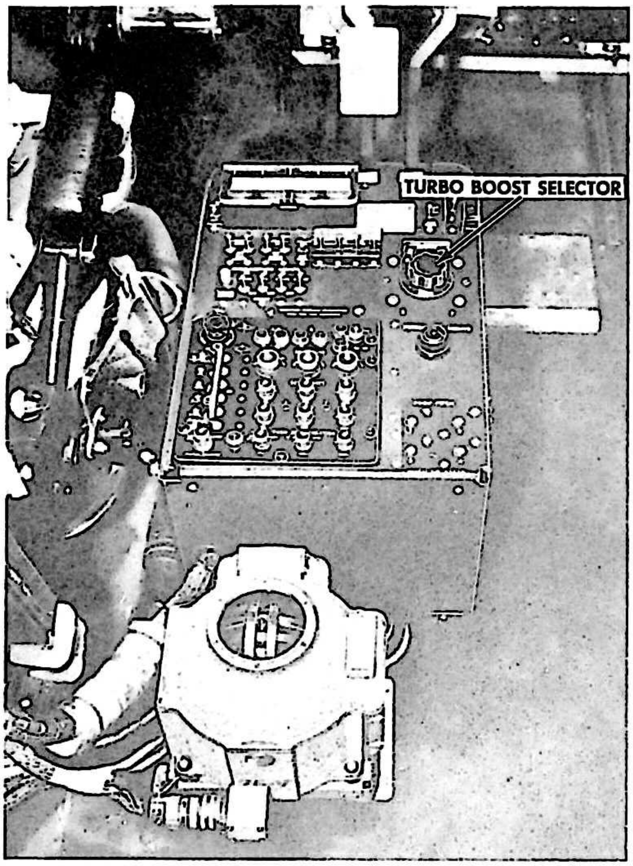
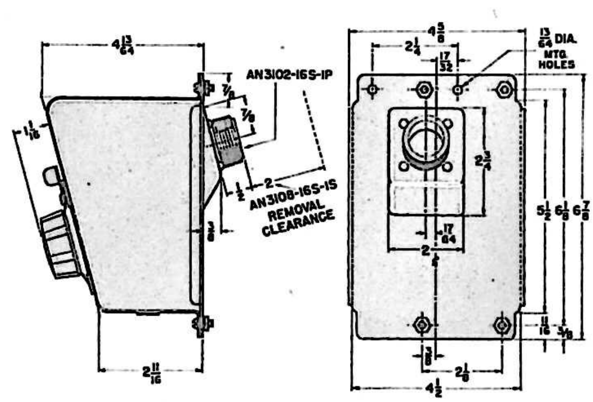


Figure 49—Location of Turbo-Boost Selector, B-29 Airplanes



AN CONNECTORS

Receptacle	AN 3102-16S-1P	Angle Plug	AN 3108-16S-1S
Straight Plug	AN 3106-16S-1S	Cable Clamp	AN 3057-8

Figure 50—Outline Dimensions of Turbo-Boost Selector

(2) MOUNTING INSTRUCTIONS. (See figure 50 for outline dimensions and clearances needed.)—When the complete turbo-boost selector with its case is mounted on top of the pedestal, it is held in place with four screws. This places the AN connector directly underneath the unit, where it can be easily reached on B-24 airplanes from the front of the pedestal. In modification installations on B-17 airplanes, it is necessary that the wiring harness be made long enough to allow for lifting the turbo-boost selector from the pedestal in order to reach the AN connector. The slack in the harness is then taken up by tying a loop in it and tying it to the bulkhead just above the hatchway at the rear of the navigator's station.

In B-17 factory installations where the unit is used without its regular case, the mechanism is mounted in a special case in such a way that the AN connector extends through the left side of the pedestal, where it is readily accessible. This places the indicator arrow on the left of the dial, and the calibrator for No. 1 engine in the lower left-hand corner; for No. 2, in the lower right-hand corner; for No. 3, in the upper right-hand corner; and for No. 4, in the upper left-hand corner.

To install the turbo-boost selector in a B-29 airplane, first remove the knob-and-dial assembly; then attach the bare unit to the under side of the control pedestal cover with the two support bolts provided. Next replace the knob-and-dial assembly and insert the AN connector. Take special care to place the washers and dial-stop plate in the correct position before screwing on the knob. When replacing the knob, hold the dial so it does not turn, screw the knob clockwise until it starts to bind on the dial, and then tighten the Allen-head screw which fixes the position of the knob on the shaft.

CAUTION

The Allen-head screw must be very tight so the dial will not turn on the shaft. The knob must not be screwed too far down on the shaft before the setscrew is tightened or it will bind on the dial and be difficult to turn. It must, however, be tight enough so the dial-stop plate engages the dial stop properly. On model G1056A4CA1 turbo-boost selectors, one side of the shaft is flat and the knob slides over the shaft instead of screwing on. The arrangement of washers under the dial has also been changed, and the spring tension against the dial does not depend upon the position of the knob.

(3) PREPARATION FOR USE.—After the turbo-boost selector is installed, check the knob to see that it turns freely but not too loosely. Be sure that it is screwed down far enough on the shaft to place sufficient tension on the spring beneath the dial so the dial will not be turned by vibration. (See Caution, paragraph 2 *a* (2), preceding.) Check the Allen-head setscrew in the knob to see that it is tight. (Use a 3/32-inch Allen-head wrench.)

b. PRESSURETROL.

(1) LOCATION.

(*a*) B-17 AIRPLANES.—In B-17 factory installations, the Pressuretrol is located in the upper part of the engine nacelle behind the fire wall and directly alongside the induction-system duct. (See figure 51.) This location may be reached by removing the cowling just behind the fire wall. On modification installations in B-17 airplanes, the Pressuretrol is mounted in a similar location in front of the fire wall.

(*b*) B-24 AIRPLANES.—In B-24 airplanes, the Pressuretrol is mounted on the left side of the carburetor intake duct just ahead of the fire wall in the accessory section. This location is reached by unbuttoning the cowling surrounding the nacelle just back of the cowl flaps. (See figure 52.)

(*c*) B-29 AIRPLANES.—In B-29 airplanes, the Pressuretrol is located on the upper left side of the engine nacelle just above the access plate. (See figures 53 and 54.) It may easily be reached by removing the upper left access plate behind the cowl flap, then reaching upward inside the access hole.

(2) MOUNTING INSTRUCTIONS. (See figure 55 for outline dimensions and clearances needed.)—Before the Pressuretrol is mounted in the airplane, attach to its sides the two small aluminum plates which are part of the mounting bracket. Then bolt these two plates to the four shock mounts on the main bracket. The plates are attached to the Pressuretrol by three mounting screws and the screws which hold the AN connector. Be sure to align the shock mounts carefully and make sure the vibration stops are in place.

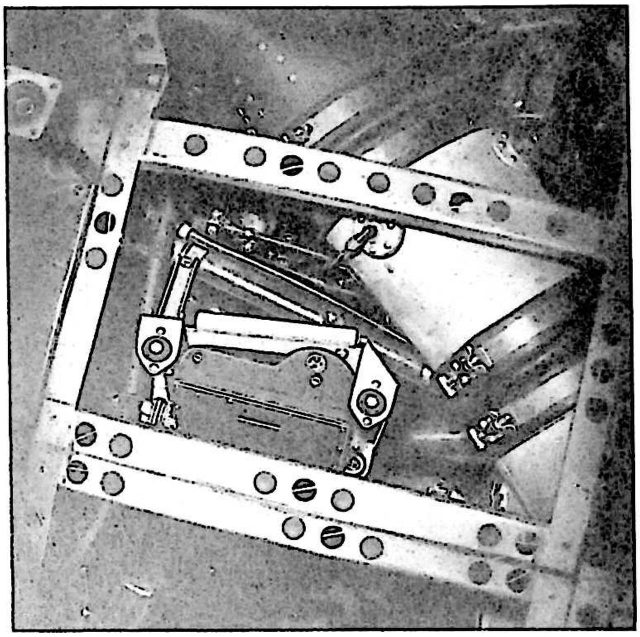


Figure 52—Pressuretrol Mounting, B-24 Airplanes

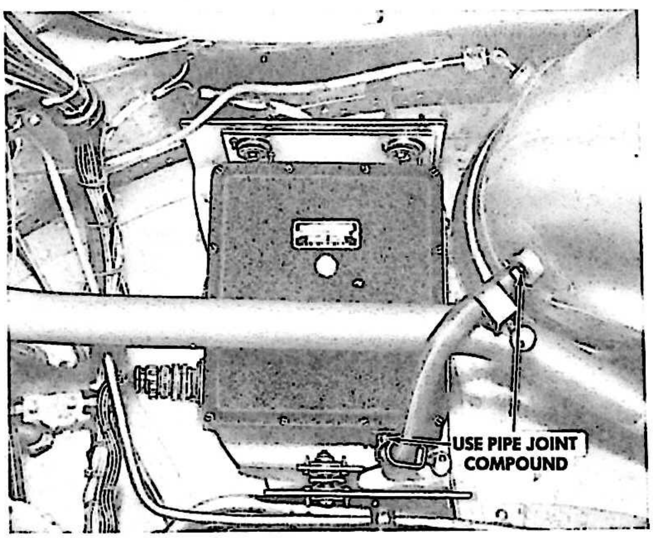


Figure 51—Pressuretrol Mounting, B-17 Airplanes

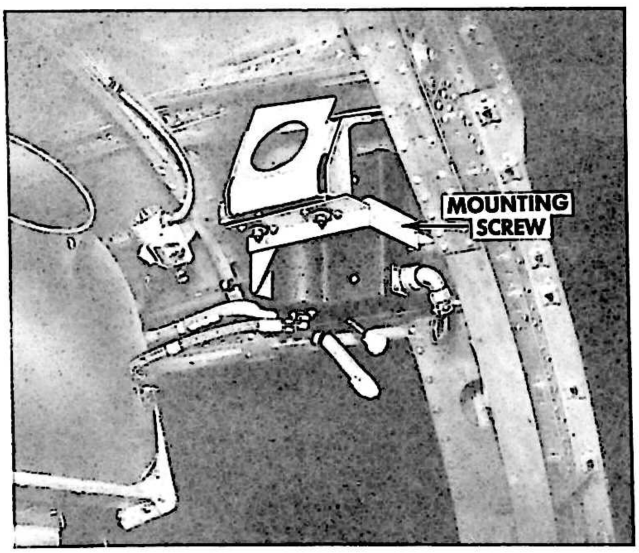


Figure 53—Pressuretrol Mounting, B-29 Airplanes

CAUTION

Be careful when screwing the mounting screws into the Pressuretrol. If the wrong thread or a damaged screw is used, aluminum chips may enter the Pressuretrol. Do not touch the two screws exposed on the top of the Pressuretrol. These screws are calibrating screws and are to be used for factory adjustments only. The calibrating screws can be distinguished by the red lacquer coating.

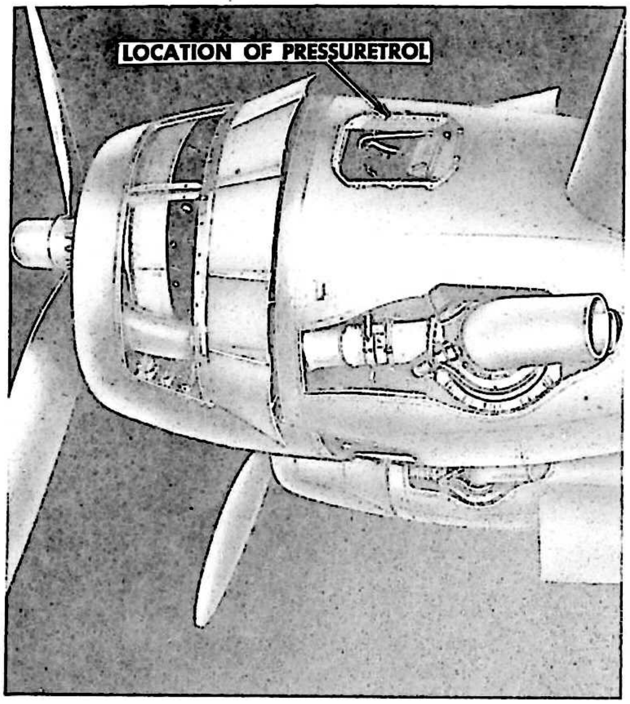


Figure 54—Pressuretrol Location, B-29 Airplanes

Insert the AN connector, being careful to align the guide key properly. Attach the Pressuretrol to the hose which connects to the carburetor intake duct. (See figure 51.) Use pipe joint compound (gasket paste, U.S. Army Specification 2-85-B) on the threaded hose connections.

(3) PREPARATION FOR USE.—When properly installed, the Pressuretrol is ready for use. Check the hose connection at both ends to make sure the hose clamps are tight. Check the shock mounting on the bracket to see that it is in good condition. Make sure the AN connector is tight. Inspect also the flexible couplings in the induction-system duct to be sure they are in good condition and the clamps are tight.

c. TURBO GOVERNOR.

(1) LOCATION.

(*a*) B-17 AIRPLANE.—The turbo governors for the outboard engines are located directly behind the turbosuperchargers. They may be reached through small access plates in the fairing directly behind the waste gate. (See figure 56.) On the inboard engines, the governors are mounted inside the wing about 15 inches to the right of the waste-gate motor. (See figure 57.)

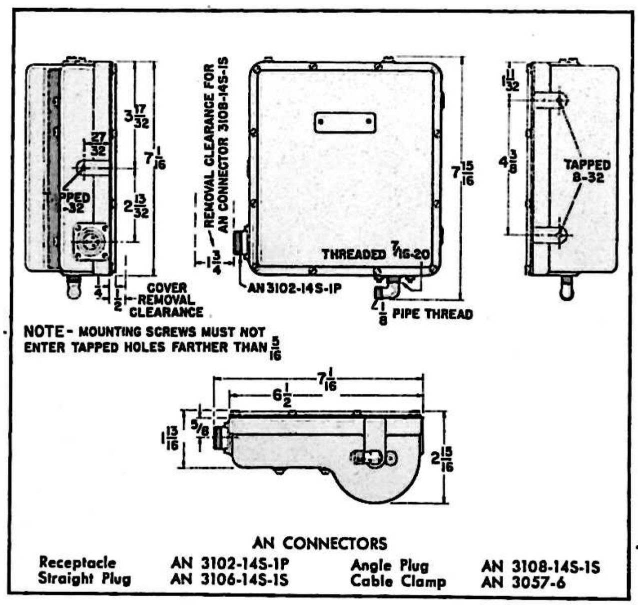


Figure 55—Outline Dimensions of Induction-System Pressuretrol

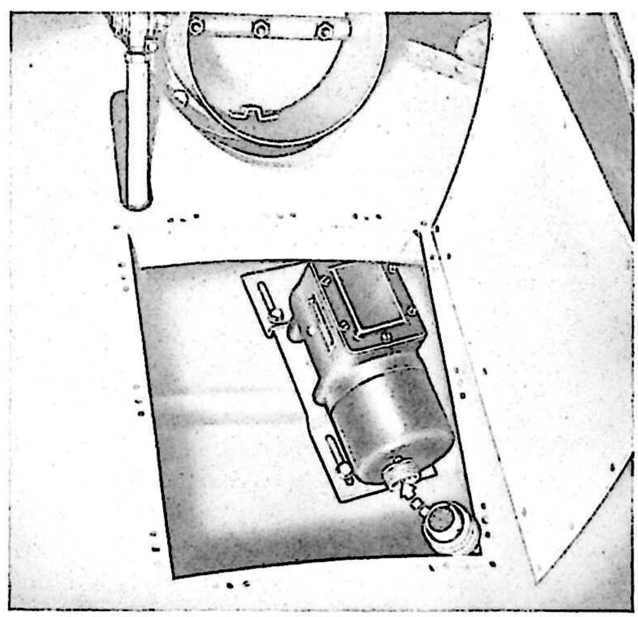


Figure 56—Governor Mounting, Outboard Engines of B-17 Airplanes

(*b*) B-24 AIRPLANE.—The governor is located just above the heat baffle plate on the turbosupercharger, about five inches away from the tachometer connection to the tùrbo shaft. (See figure 58.) This location, which is identical in all four engines, is accessible by removing the fairing around the turbosupercharger.

(*c*) B-29 AIRPLANE.—The governor is located on the right side of each engine directly in the rear of the turbo drive shaft. Only one governor is used to control both turbos on each engine; it is driven by the turbo on the right side of the engine. One governor is sufficient for both turbos because both waste gates are driven by one waste-gate motor and the duct from the compressors of the two turbos are brought together in one induction-system chamber. To reach the governor on the outboard engines, it is necessary to remove a small access plate on the right side of the nacelle just behind the turbosupercharger. (See figure 59.) On the inboard engine, remove the lower half of the narrow sheet-metal plate surrounding the turbine. (See figure 60.)

(2) MOUNTING INSTRUCTIONS. (See figure 61 for outline dimensions and clearances needed.)—Special brackets are provided for mounting the governor in the airplane. Generally it is necessary to fasten the governor to the mounting bracket and safety wire the mounting screws before the governor can be in-

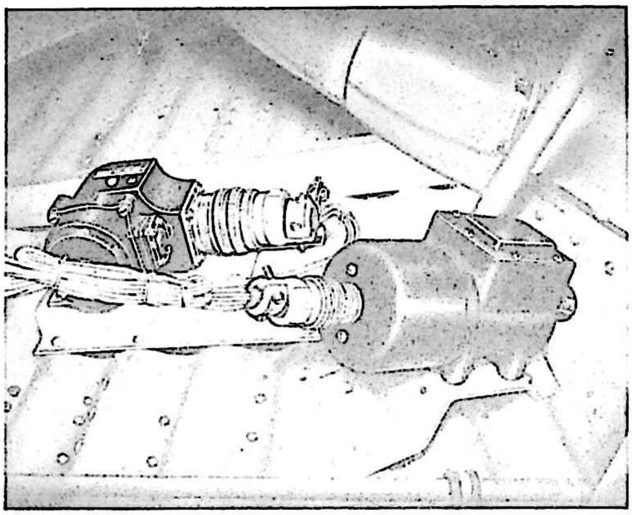


Figure 57—Governor and Waste-Gate-Motor Mountings, Inboard Engines of B-17 Airplanes

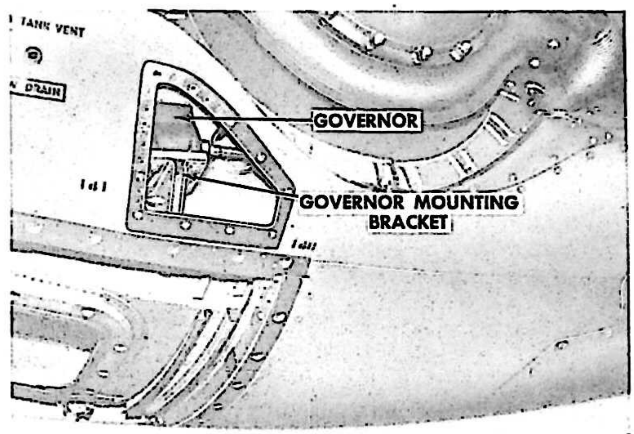


Figure 59—Governor Mounting, Outboard Engines of B-29 Airplanes

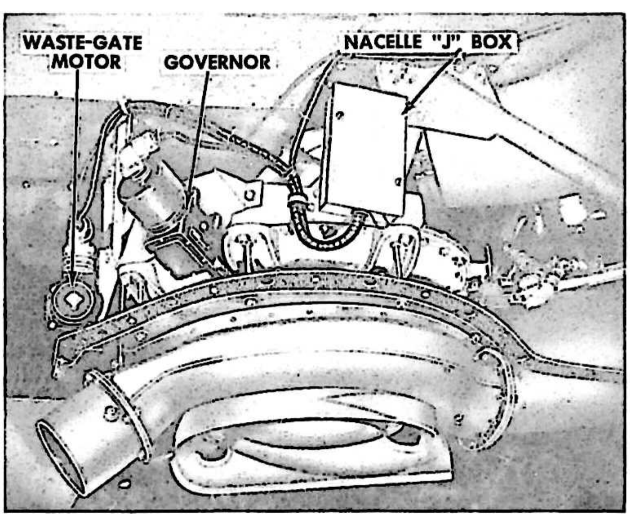


Figure 58—Mounting of Turbo Control Units on Turbosupercharger of B-24 Airplanes

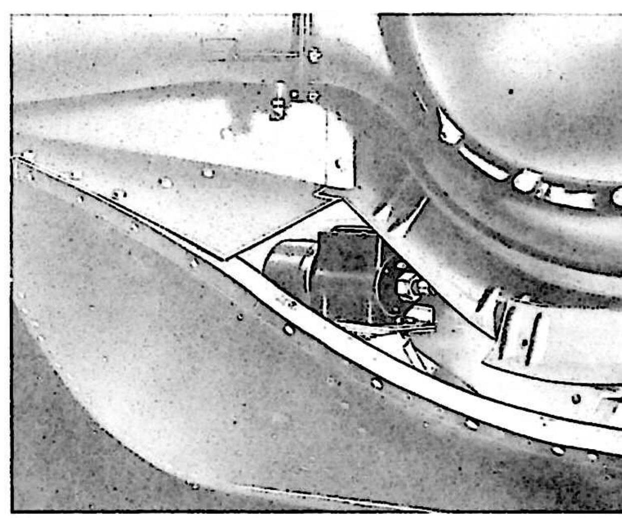
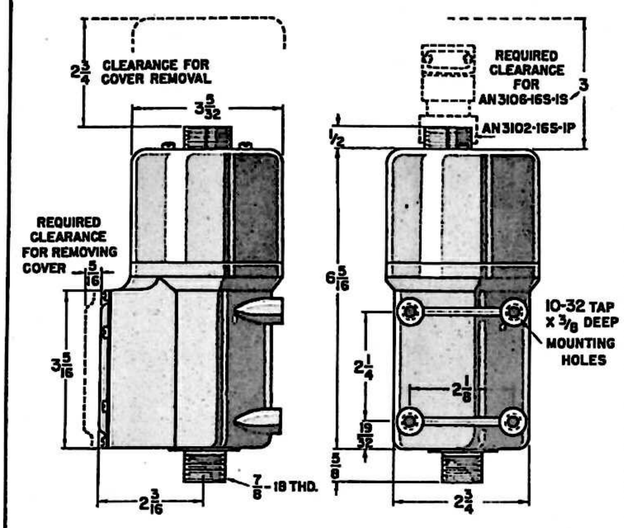


Figure 60—Governor Mounting, Inboard Engines of B-29 Airplanes



AN CONNECTORS

Receptacle	AN 3102-16S-1P	Angle Plug	AN 3108-16S-1S
Straight Plug	AN 3106-16S-1S	Cable Clamp	AN 3057-8

Figure 61—Outline Dimensions of Turbo Governor

stalled in the airplane. In some B-17 installations, however, the governor should be attached to the bracket after the bracket is mounted in the airplane, and then safety wired. On the outboard engines of a B-29 airplane, place the mounting bracket in the airplane first, and then attach the governor.

After fastening the mounting bracket to the airplane, attach the AN connector; then connect the flexible drive to the tachometer connection on the turbine. Make sure that the nut on the flexible drive is drawn up tight without cross-threading, and be sure also that the governor mounting does not produce a compound bend in the flexible drive. (See paragraph *d* following.)

NOTE

The oil pumps on turbosuperchargers are not all of the same manufacture, and therefore have different lengths of accessory shafts. Therefore, when a turbosupercharger is replaced, it may be necessary to move the governor bracket in order to reconnect the flexible drive properly.

(3) PREPARATION FOR USE.—After the turbo governor has been mounted securely and the flexible drive has been connected, the unit is ready for operation.

d. FLEXIBLE DRIVE.

(1) LOCATION.—The flexible drive is attached to the tachometer connection on the turbosupercharger just above the heat baffle between the turbine wheel and the compressor. (See figure 62.)

(2) MOUNTING INSTRUCTIONS.

CAUTION

Before installing a new flexible drive, remove the split brass washer from the end which connects the flexible drive to the turbosupercharger. This washer is put on merely to keep the shaft from slipping out of its housing while in shipment. It has no other useful purpose.

After removing the brass washer (figure 31), pull the shaft from the housing and lubricate it with grease, Specification AN-G-3a. Replace the flexible shaft in its housing; then fasten the end of the flexible drive from which the washer was removed to the tachometer connection on the turbosupercharger. On B-29 airplanes, it is necessary to remove the turbosupercharger in order to make this connection. Once the housing is attached to the turbosupercharger, it may be left in place. The flexible shaft can be pulled from the housing and replaced in the housing very easily. Whenever replacing the flexible shaft in a housing that is attached to the turbosupercharger, merely press inward on the shaft and turn the shaft slowly until it engages with the drive on the turbo. The other end of the flexible drive may then be attached to the turbo governor.

It is important that the flexible drive have a slight bend to keep the shaft from whipping in the

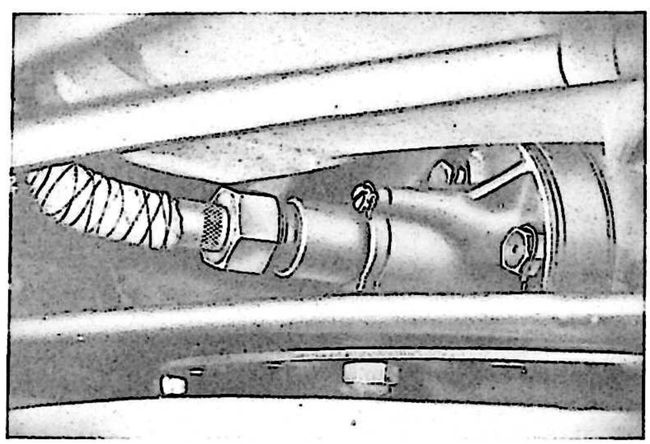


Figure 62—Flexible-Drive Connection to Turbosupercharger

housing. There should not, however, be a compound bend in the drive, and it may be necessary to use washers under some of the corners of the governor mountings to prevent a compound bend in the flexible drive.

(3) PREPARATION FOR USE.—After the flexible drive has been mounted securely to the turbo-supercharger and the turbo governor, the unit is ready for use.

e. AMPLIFIERS.

(1) LOCATION.

(*a*) B-17 AIRPLANE.—The amplifiers for engines No. 1 and No. 4 are located in the aft region of the camera well. (See figure 63.) The amplifiers for No. 2 and No. 3 engines are on the floor of the radio compartment behind bulkhead 5. The spare amplifier is located just above the floor at the rear of the radio room on the right side of the aisle. (See figure 64.)

(*b*) B-24 AIRPLANE.—In some installations, the amplifiers are located beneath the floor of the radio room between stations 2.0 and 4.0. (See figures 65, 66, and 67.) On other installations, the amplifiers are mounted on one platform at station 4.0.

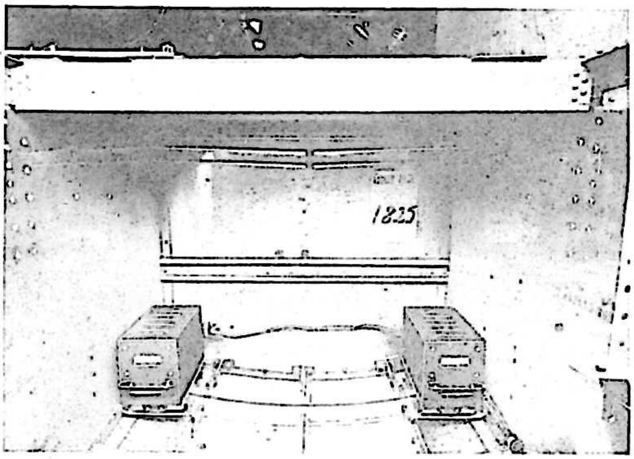


Figure 63—Amplifiers No. 1 and No. 4, Aft, B-17 Airplanes

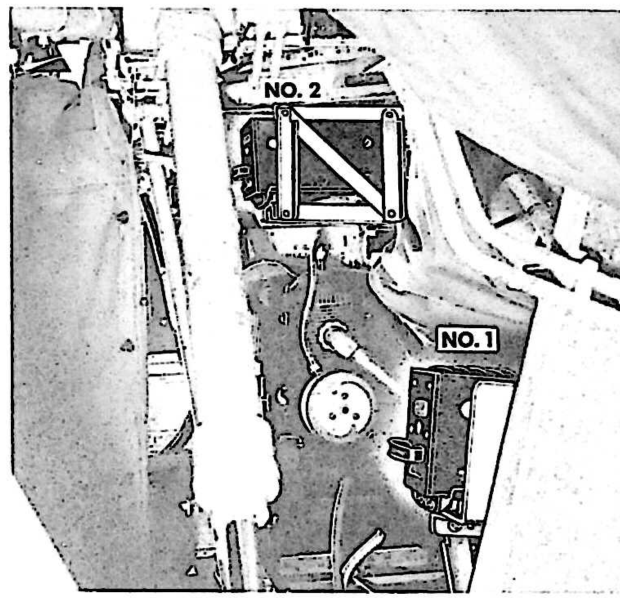


Figure 65—Amplifiers No. 1 and No. 2, B-24 Airplanes, Looking Toward Rear From Side of Nose Wheel

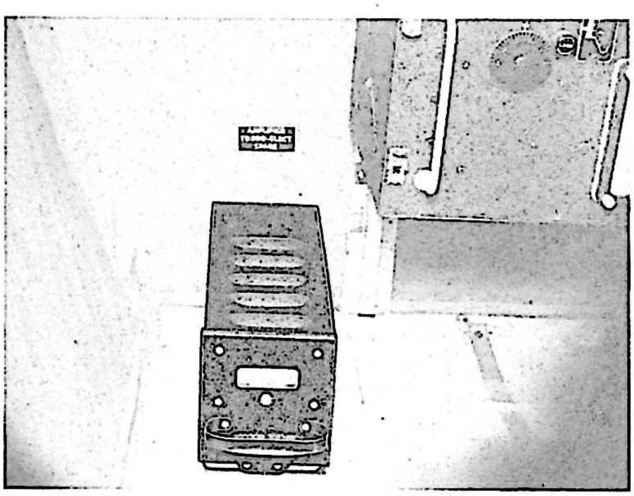


Figure 64—Spare Amplifier, Rear of Radio Room, B-17 Airplanes

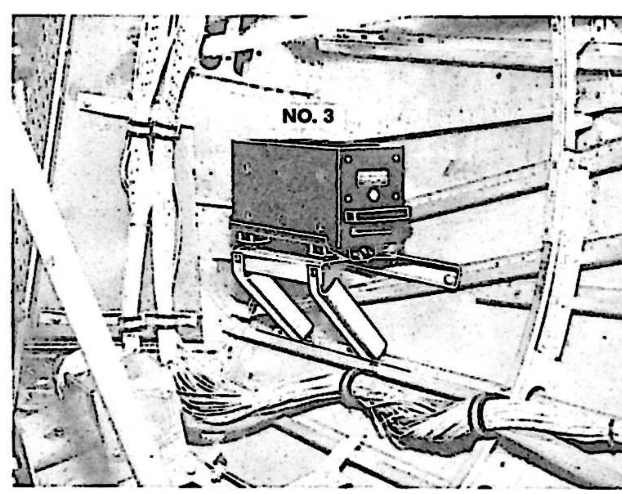


Figure 66—No. 3 Amplifier, Looking Forward From Station 4.0, B-24 Airplanes

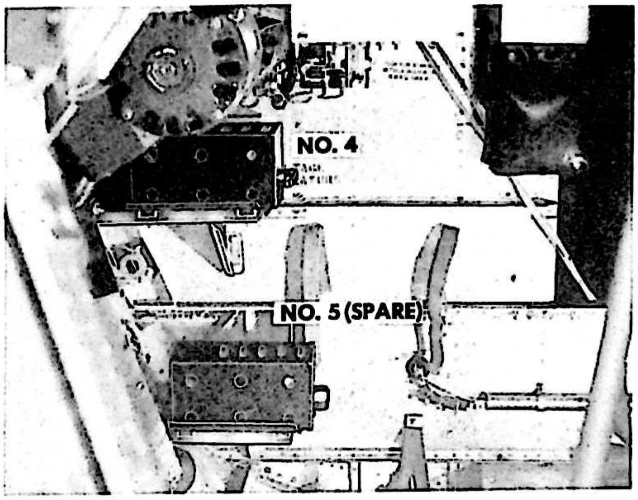


Figure 67—Amplifiers No. 4 and 5 (Spare) Viewed From Station 3.0, B-24 Airplanes

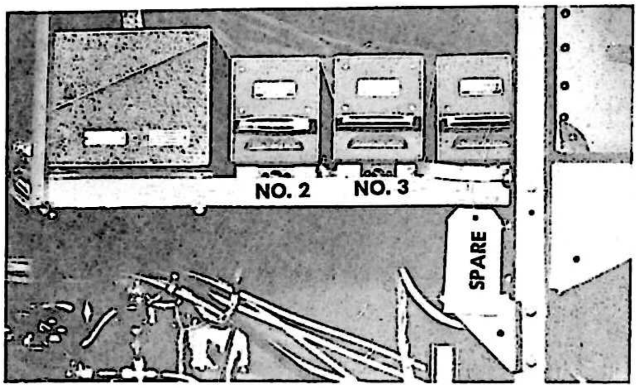


Figure 68—Amplifiers for Inboard Engines, and Spare Amplifier, B-29 Airplanes

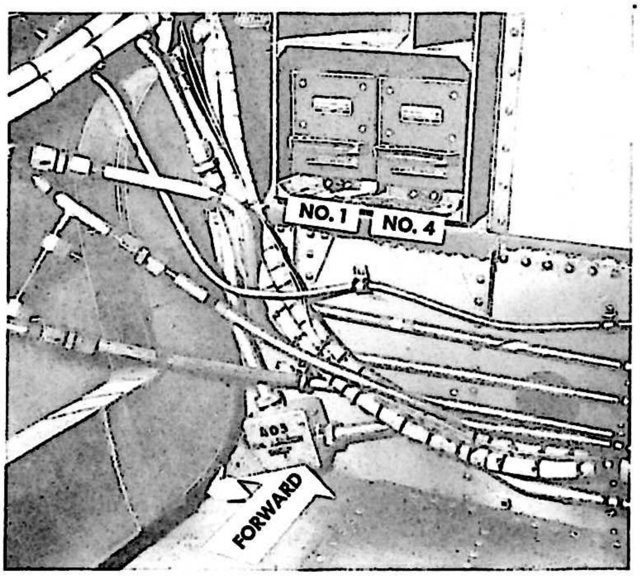
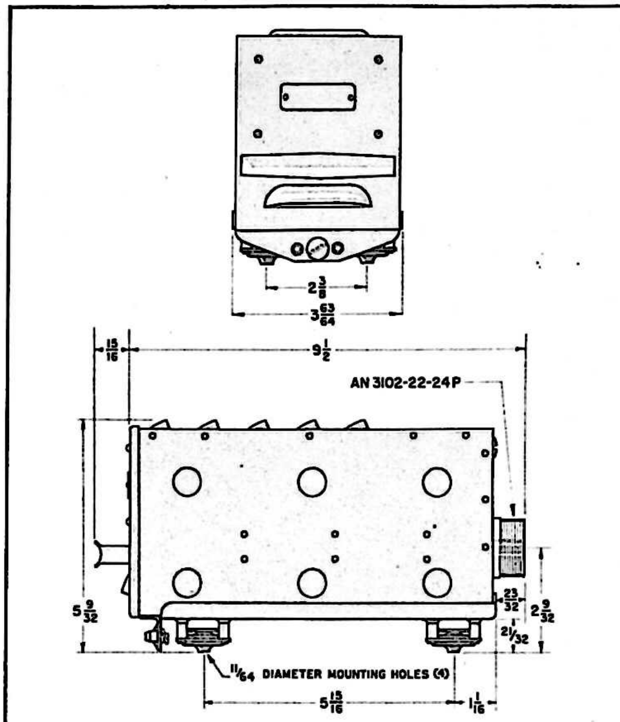


Figure 69—Amplifiers for Outboard Engines, B-29 Airplanes



AN CONNECTORS

Receptacle	AN 3102-22-24P	Angle Plug	AN 3108-22-24S
Straight Plug	AN 3106-22-24S	Cable Clamp	AN 3057-12

Figure 70—Outline Dimensions of Turbo Control Amplifier

(*c*) B-29 AIRPLANE.—The amplifiers are conveniently located in the navigator's compartment, directly behind the pilot. The amplifiers for the inboard engines and the spare amplifier are mounted side by side on a platform directly above the navigator's map case. (See figure 68.) The amplifiers for the outboard engines are mounted in a compartment below the navigator's table, facing the rear of the airplane. (See figure 69.)

(2) MOUNTING INSTRUCTIONS. (See figure 70 for outline dimensions and clearances needed.)—A separate, shock-mounted base or platform is generally used for each amplifier. To mount the amplifier, place it on the shock-mounted base and lock it in place with the one Dzus fastener provided for that purpose; then attach the AN connector.

(3) PREPARATION FOR USE.—After properly mounting the amplifier, check the AN connector to see that it is tight. Be sure that nothing is placed on top of the case which would prevent proper ventilation. After the inverter is turned on, allow approximately two minutes for the amplifier to warm up sufficiently for proper operation.

f. WASTE-GATE MOTOR.

(1) LOCATION.

(*a*) B-17 AIRPLANE.—The waste-gate motor is located about 15 inches away from the waste gate and almost directly above it. On the outboard engines, this location may be reached by removing an access plate in the fairing. (See figure 71.) On the inboard engines, it is necessary to remove the flap control inspection door in the lower wing surface and then disconnect the flap control rod and crawl forward about four feet inside the wing. (See figures 57 and 72.)

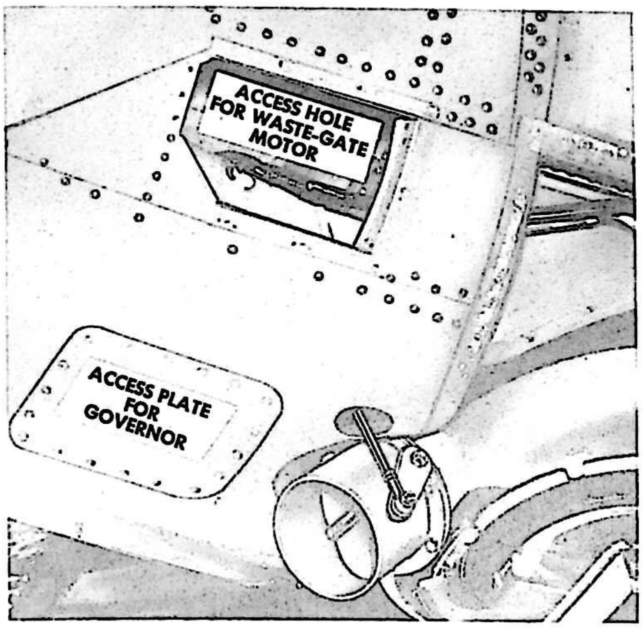


Figure 71—Access Plates for Waste-Gate Motor and Governor, Outboard Engines, B-17 Airplanes

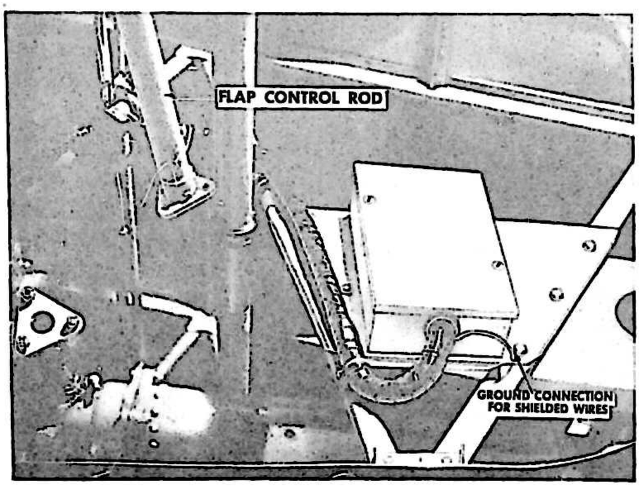


Figure 72—Access Hole and Nacelle "J" Box, Inboard Engines, B-17 Airplanes

(*b*) B-24 AIRPLANE.—The waste-gate motor is located about 10 or 12 inches directly above the waste gate. This location, identical on all four engines, is easily accessible by removing the fairing which surrounds the turbosupercharger. (See figure 73.)

(*c*) B-29 AIRPLANE.—One waste-gate motor is used for each engine. It operates the waste gates of both turbosuperchargers simultaneously through a mechanical linkage. The base of the motor is mounted directly above the turbine wheel housing on the turbo about 6 inches from the upper edge of the turbine wheel. On engines No. 1 and No. 3, the motors are on the right side of the nacelles above the right-hand turbosupercharger. On engines No. 2 and No. 4, the waste-gate motor is located on the left side of the nacelle directly above the left-hand turbosupercharger. (See figures 74 and 75.)

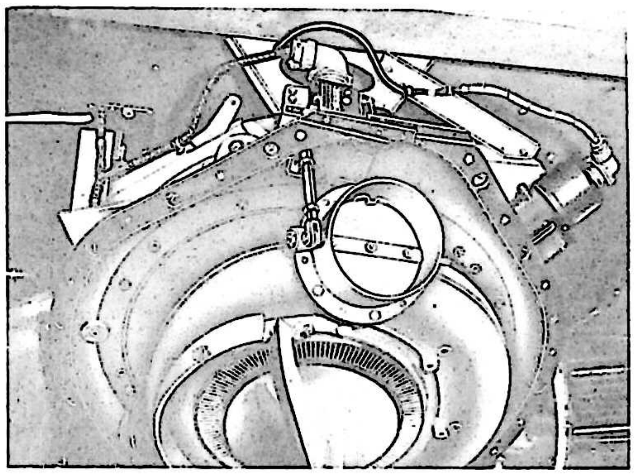


Figure 73—Waste Gate in Closed Position, B-24 Airplanes

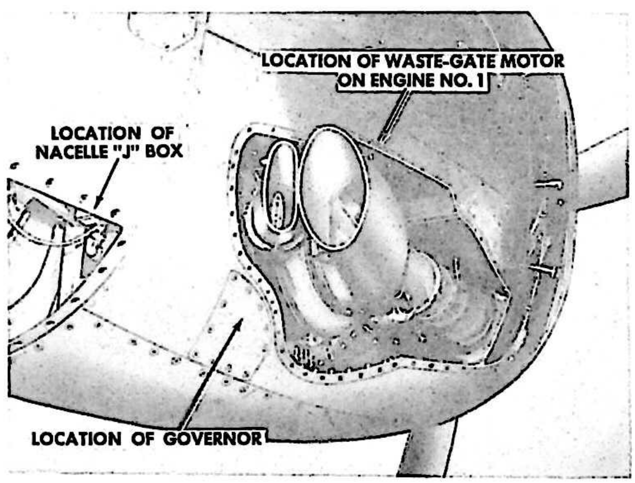


Figure 74—Locations of Waste-Gate Motor, Governor, and Nacelle "J" Box, No. 1 Engine of B-29 Airplanes

(2) MOUNTING INSTRUCTIONS. (See figure 76 for outline dimensions and clearances needed.)—A heavy aluminum bracket is provided by the aircraft factory for mounting each waste-gate motor. The motor is bolted to the bracket, and the mounting bolts are safety wired with brass or steel wire. In some airplanes the mounting bracket need not be removed when the waste-gate motors are removed. (See figure 77.)

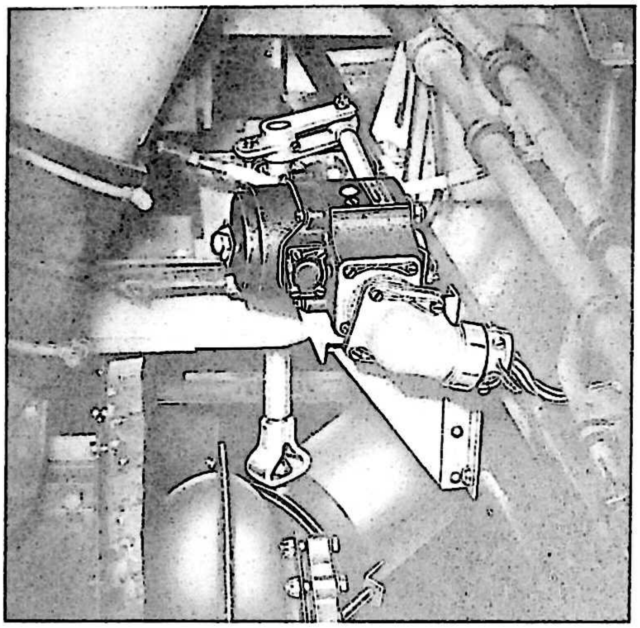


Figure 75—Waste-Gate-Motor Mounting and Linkage, B-29 Airplanes

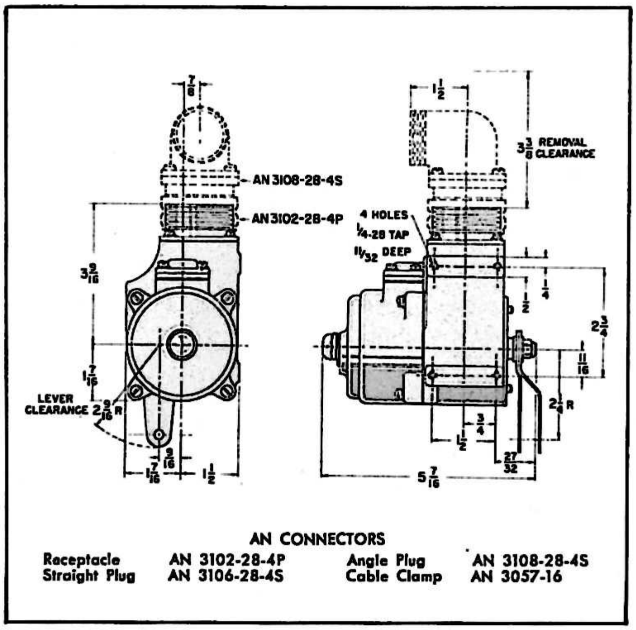


Figure 76—Outline Dimensions of Waste-Gate Motor

CAUTION

Note that one of the four holes in the base of the motor is not as deep as the rest. Be sure the short screw is used in the shallow hole.

When mounting the motor to the bracket already in the airplane, make sure the bracket has not moved and that the motor shaft is parallel with the shaft of the waste gate (except on the B-29), so there will be no binding at the linkage bearings when the motor rotates. *Before connecting the linkage, run the motor against its stop in the fully closed position.* To do this, use a separate calibrator potentiometer wired to an AN-connector receptacle of the same size and type as that used on the Pressuretrol. (See figure 78.) Disconnect the Pressuretrol and attach this special test potentiometer in its place. The waste-gate motor

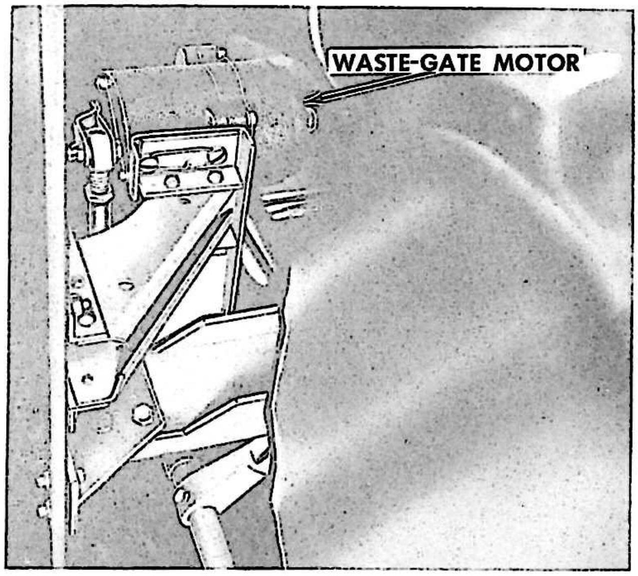


Figure 77—Mounting Bracket for Waste-Gate Motor, B-29 Airplanes

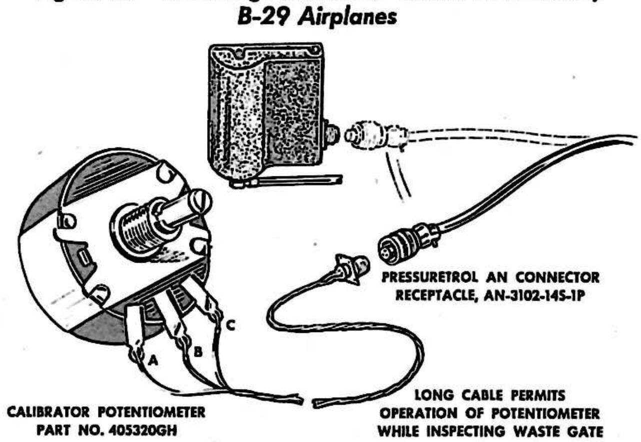


Figure 78—Service Test Potentiometer

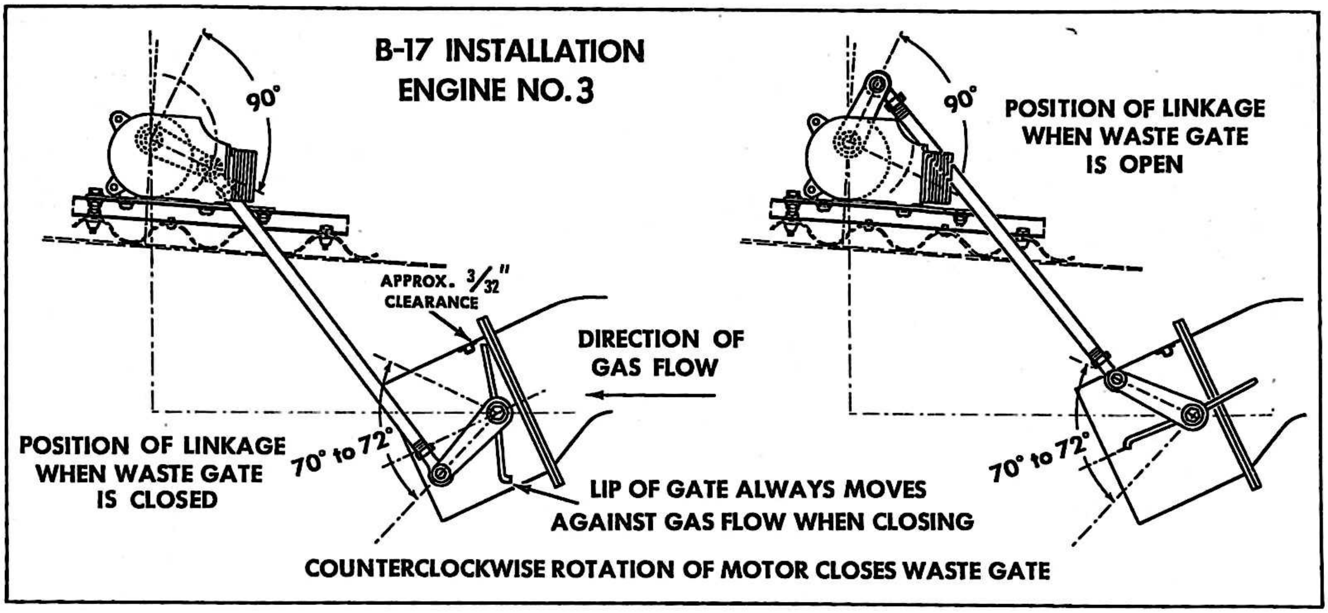


Figure 79—Relative Positions of Waste-Gate-Motor Arm and Waste-Gate Arm on a Typical Installation

can be run in either direction by merely moving the wiper of the test potentiometer.

If a spare calibrator potentiometer is not available, solder a small battery clip to each end of a piece of insulated wire about five or six inches long. Attach one clip to terminal A3 and the other clip to terminal A1 in the main "J" box. The waste gates for engine No. 1 can then be opened and closed as desired by turning the dial of the turbo-boost selector. To run the motor to closed position on engine No. 2, attach the clips to terminals A2 and A4; on engine No. 3, attach them to terminals C1 and C3; and on engine No. 4, to terminals C2 and C4.

CAUTION

Do not short any other terminals in the "J" box, as this might result in damage to some part of the turbo control system. Also, do not apply any shorts or grounds to terminals in the nacelle "J" box, as the result may be harmful to some of the units.

Connect the linkage to the motor crank arm. Check the waste gate to see that it is approximately 3/32 inches away from the stop in its closed position. (See figure 79.)

NOTE

The shaft on the waste-gate motor is splined so that the motor crank arm may be adjusted in steps of 22½ degrees; however, before it leaves the factory, the arm is placed in a definite position relative to the mechanical stops inside the motor, and in most cases the position of this arm need not be changed.

The direction of rotation of the motors to close the waste gate may be different for different engines. To reverse the direction of rotation of a waste-gate motor after it is mounted, reverse four leads in the nacelle "J" box. For the proper leads to reverse, see the notation on the wiring diagram, figure 128.

See that the motor crank arm is in the proper position relative to the position of the waste-gate arm.

CAUTION

The position of the waste-gate-motor arm in relation to that of the waste-gate arm is very important, because of the flow characteristics of the waste gate. A slight movement of the gate as it nears the closed position has much more effect on the turbosupercharger than the same amount of movement when the gate is near the open position. When the waste-gate motor is running, the rate of movement of its arm is constant; but since the two arms operate in different quadrants, the resulting movement of the waste gate is slower as it nears the closed position and faster near the open position. (See figure 80.) This relationship also gives a mechanical advantage to the

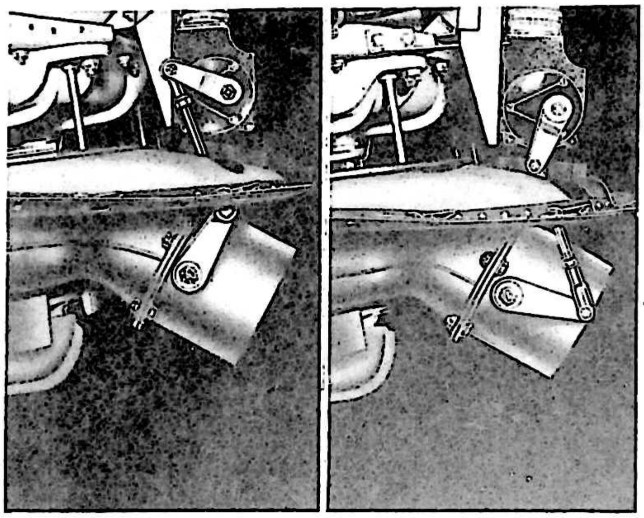


Figure 80—Waste-Gate Linkage, B-24 Airplanes. Left, Open Position; Right, Closed Position

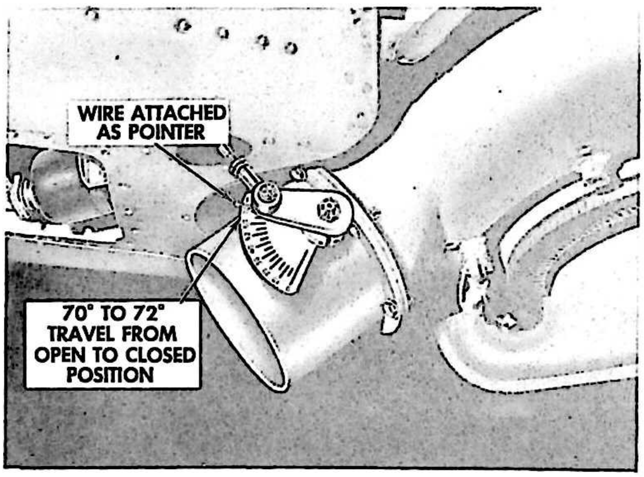


Figure 81—Waste Gate Open, B-17 Installation

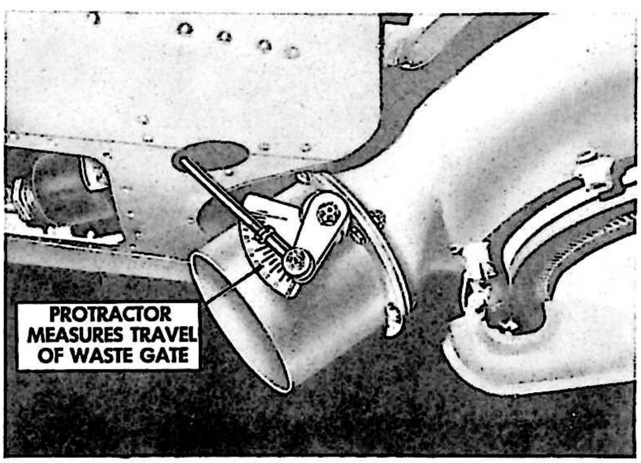


Figure 82—Waste Gate Closed, B-17 Installation

waste-gate motor as the gate nears the closed position.

(3) PREPARATION FOR USE.—After the motor is installed and the linkage connected, check the operation of the motor through its full 90-degree operating range. With normal atmospheric pressure on the Pressuretrol, the waste gate will not go to the fully closed position even with the dial of the turbo-boost selector set at "10." (Refer to preceding paragraph for method of closing waste gate.)

Check the waste gate when it is closed to see that it is approximately 3/32 inch away from the stop. The length of the linkage rod can be adjusted to get the proper clearance. When the proper clearance has been obtained in the closed position, place a protractor behind the waste-gate arm and check the degrees of travel from fully closed to fully open position. The waste-gate arm should travel not less than 70 degrees and not more than 72 degrees. (See figures 81 and 82.) To obtain the proper range of travel of the waste gate, it may be necessary to shift the position of the motor mounting bracket, or change the position of the waste-gate arm if an adjustable arm is provided, and again change the length of the linkage rod to give proper clearance in closed position.

CAUTION

Only slight changes should be made in the length of the linkage rod. When operating, the motor arm travels approximately 90 degrees, while the waste-gate arm travels only 70 to 72 degrees. Any major change in the length of the rod will upset the range of travel of the waste gate. Major adjustments must be made by repositioning the motor crank arm on the motor shaft or the waste-gate arm on the waste-gate shaft, or by shifting the motor.

Open and close the waste gate a few times, checking the linkage for any indication of binding at the bearings or rubbing of the rod against the cowling or lower wing surface.

NOTE

If a turbosupercharger is to be replaced, disconnect its linkage at the waste-gate end. After reconnecting the linkage upon replacement, check its operation in the same manner as outlined above. This check should be repeated after the turbo has been run in or after its first flight, as the position of the turbosupercharger may shift slightly when it "sets" after its first high-temperature operation.

g. NACELLE "J" BOX.

(1) LOCATION.

(*a*) B-17 AIRPLANE.—On the outboard engines, the nacelle "J" boxes are located inside the nacelle proper. This location may be reached by removing a small access plate on the lower surface of the nacelle just behind the fire wall. (See figure 83.) On the inboard engines, the nacelle "J" boxes are located inside the wing behind the nacelle and may be reached by removing the flap control inspection door in the lower wing surface. (See figure 72.) This is the same access door which must be removed to reach the waste-gate motor and the turbo governor on these two engines.

(*b*) B-24 AIRPLANE.—The nacelle "J" boxes are mounted on the supercharger mounting brackets just above the heat baffle on all four engines. This location is accessible after the fairing around the turbosupercharger is removed. All four "J" boxes are located on the inboard side of their respective turbos. (See figure 58.)

(*c*) B-29 AIRPLANES.—On engines No. 1 and No. 4, the nacelle "J" box is located directly to the rear of the right-hand turbo. It can be reached by removing the fairing which extends across the bottom of the nacelle. (See figure 84.) On engines No. 2 and No. 3, the nacelle "J" boxes are located in the wheel well. (See figure 85.)

(2) MOUNTING INSTRUCTIONS. (See figure 86 for outline dimensions.)— The nacelle "J" box is anchored in position with three small bolts through the bottom of the box. On the outboard engines of a B-17 airplane, it is anchored directly to a regular support structure in the nacelle. On the inboard engines in a B-17, a special aluminum bracket is provided for mounting the nacelle "J" box to the wing support member. On B-24 airplanes, the nacelle "J" box is anchored to one of the brackets supporting the turbosupercharger. In B-29 airplanes, the nacelle "J" box is anchored to a nacelle bulkhead. The mounting is similar on all four engines and no special brackets are required.

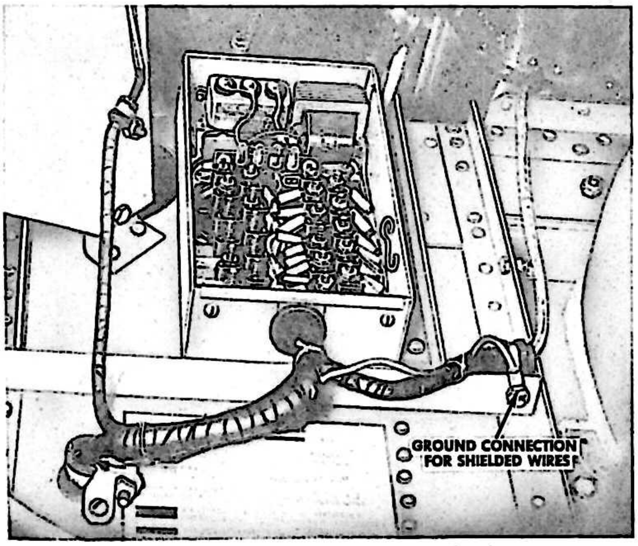


Figure 83—Mounting of Nacelle "J" Box, Outboard Engines of B-17 Airplanes

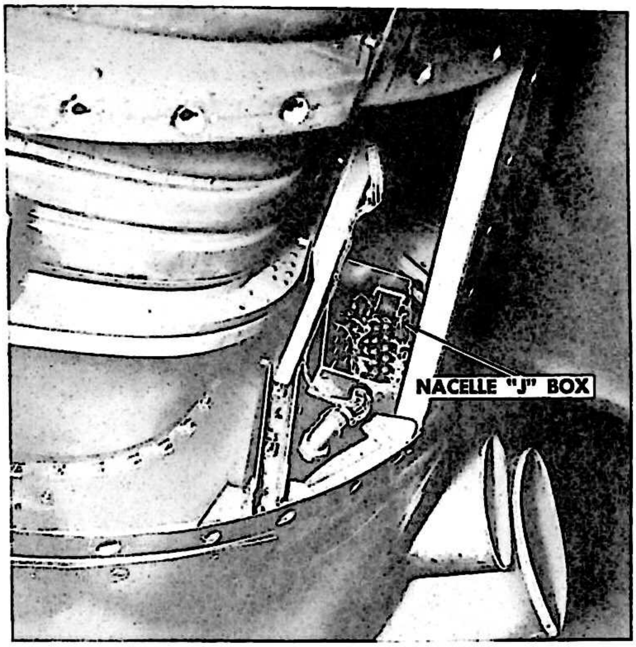


Figure 84—Mounting of Nacelle "J" Box, Outboard Engines of B-29 Airplanes

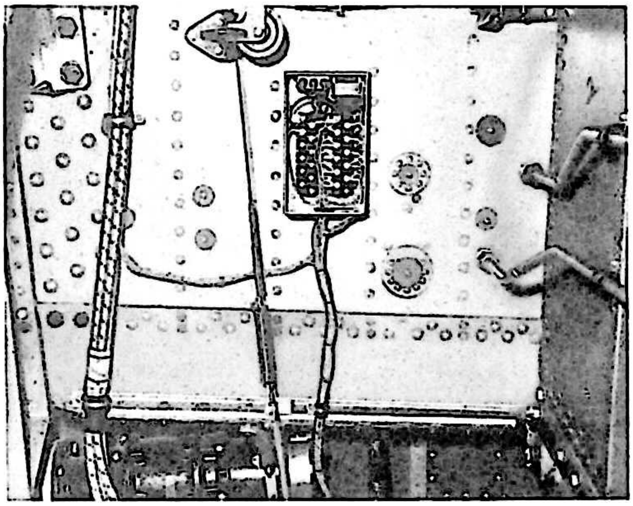


Figure 85—Mounting of Nacelle "J" Box, Inboard Engines of B-29 Airplanes

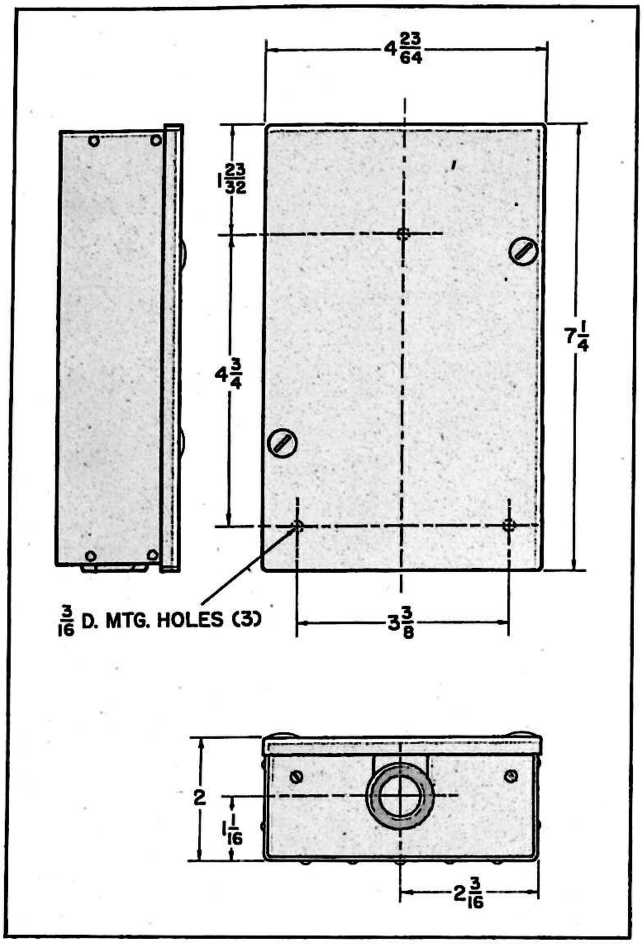


Figure 86—Outline of Nacelle Junction Box

(3) PREPARATION FOR USE.—After all four nacelle "J" boxes and the main "J" box have been installed, it is necessary to wire the complete system as outlined in paragraph 3 following.

b. MAIN "J" BOX.

(1) LOCATION.

(*a*) B-17 AIRPLANE.—The main "J" box is located approximately at station 5 beneath the floor of the radio room against the left wall of the hatchway. (See figure 87.)

(*b*) B-24 AIRPLANE.—The main "J" box is located beneath the floor of the radio room at station 3.2, approximately in the center of the airplane and in front of the hatchway. It is fastened to the under side of the floor of the radio room. (See figure 88.)

(*c*) B-29 AIRPLANE.—The main "J" box is located to the rear of the navigator's station about halfway up the wall on the left side of the fuselage. (See figure 89.)

(2) MOUNTING INSTRUCTIONS. (See figure 90 for outline dimensions.)—The "J" box is anchored to the floor or wall with four bolts through the bottom of the box.

(3) PREPARATION FOR USE.—After all four nacelle "J" boxes and the main "J" box have been in-

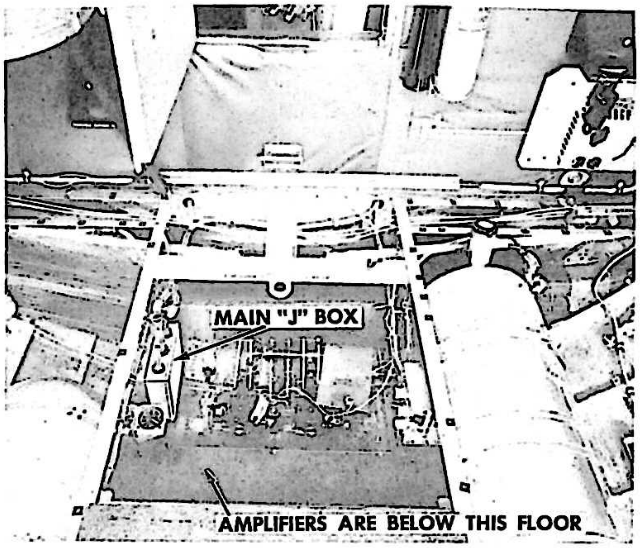


Figure 87—Main "J" Box, B-17 Airplanes

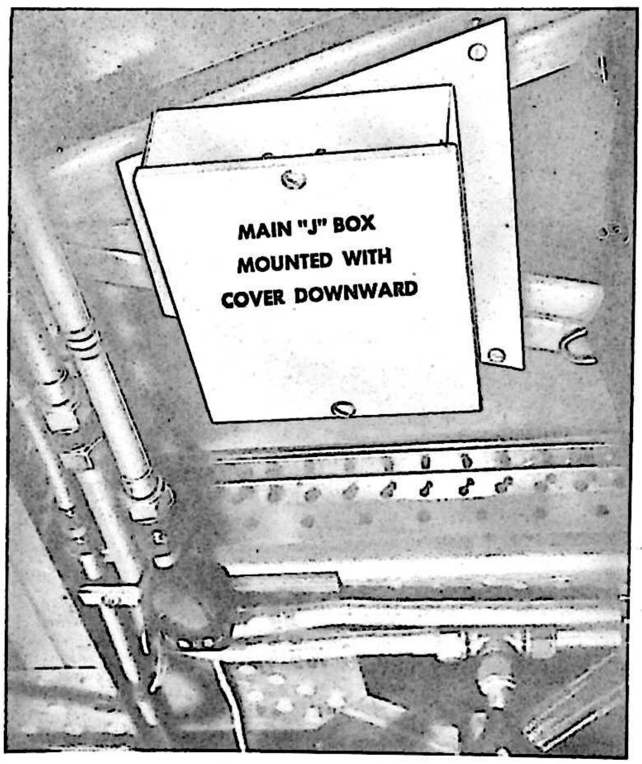


Figure 88—Main "J" Box, B-24 Airplanes

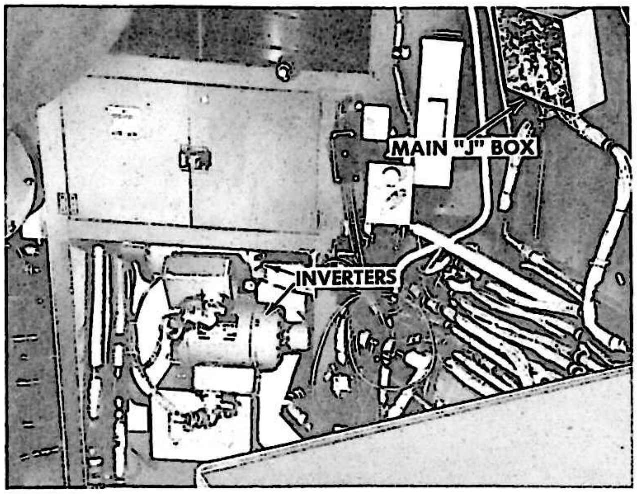


Figure 89—Main "J" Box, B-29 Airplanes

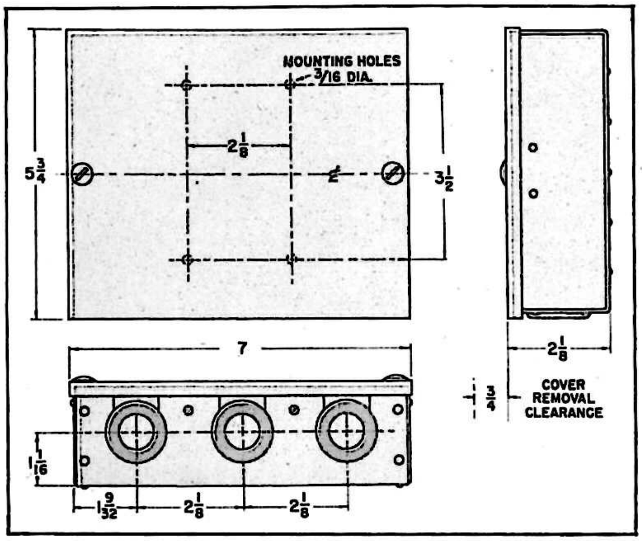


Figure 90—Outline Dimensions of Main "J" Box

stalled, it is necessary to wire the complete system as outlined in paragraph 3 following.

3. WIRING OF THE SYSTEM.

After all the individual units of the system have been installed, the operating units are connected to the nacelle "J" boxes and to the main "J" box by cable harnesses which pass through the wing structure. In some airplanes the harnesses are made in sections, and the separate sections joined together by wing disconnects and nacelle disconnects to permit easy separation of the harnesses. On B-24 and B-29 airplanes, cables pass through the leading edge of the wing. (See figures 91 and 92.) All cables are anchored to the airplanes by means of Adel or Tinnerman clamps. Where the cables may be subjected to abrasive wear, they are taped and shellacked. Wherever the cables pass through a hole in the airplane structure, the hole is fitted with a suitable grommet to protect the wire. It is very important that the slack in the cables is equally distributed between clamps to allow for bending of the wings in flight without placing strain on the cables.

Figure 93 is a complete unit and cable layout diagram for a turbo control system installation in a B-17 airplane. Refer to figure 2 for a similar layout diagram of a B-24 airplane.

The power for the complete turbosupercharger control system is taken from the same two 400-cycle, 115-volt rotary inverters which supply the power for the Autosyn instruments and the radio compass. The main power connection is made at the inverter fuse

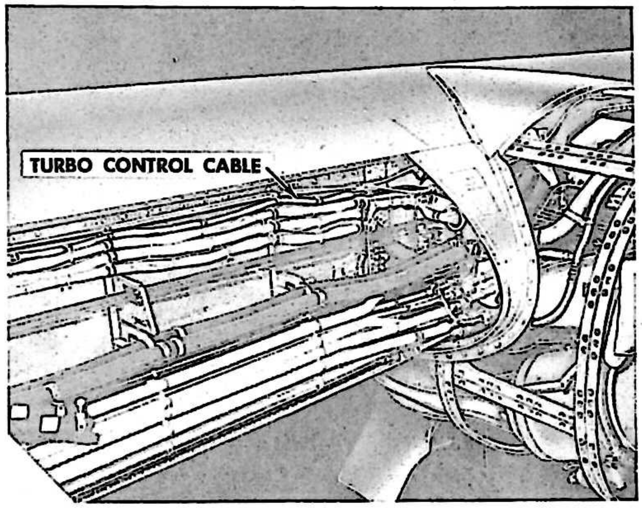


Figure 91—Location of Main Turbo Control Cables, B-24 Airplanes

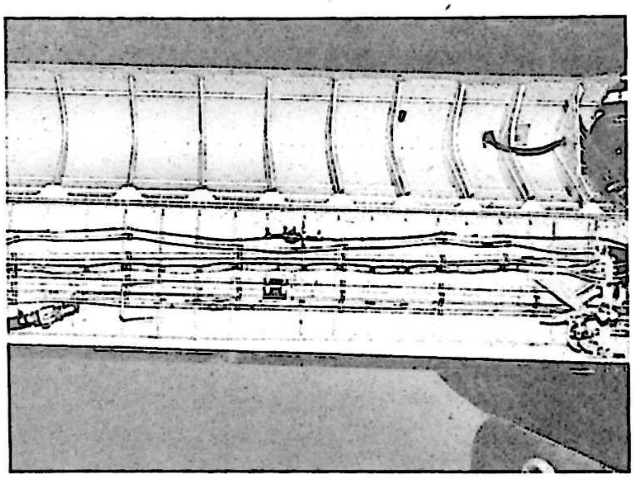


Figure 92—Location of Main Turbo Control Cables, B-29 Airplanes

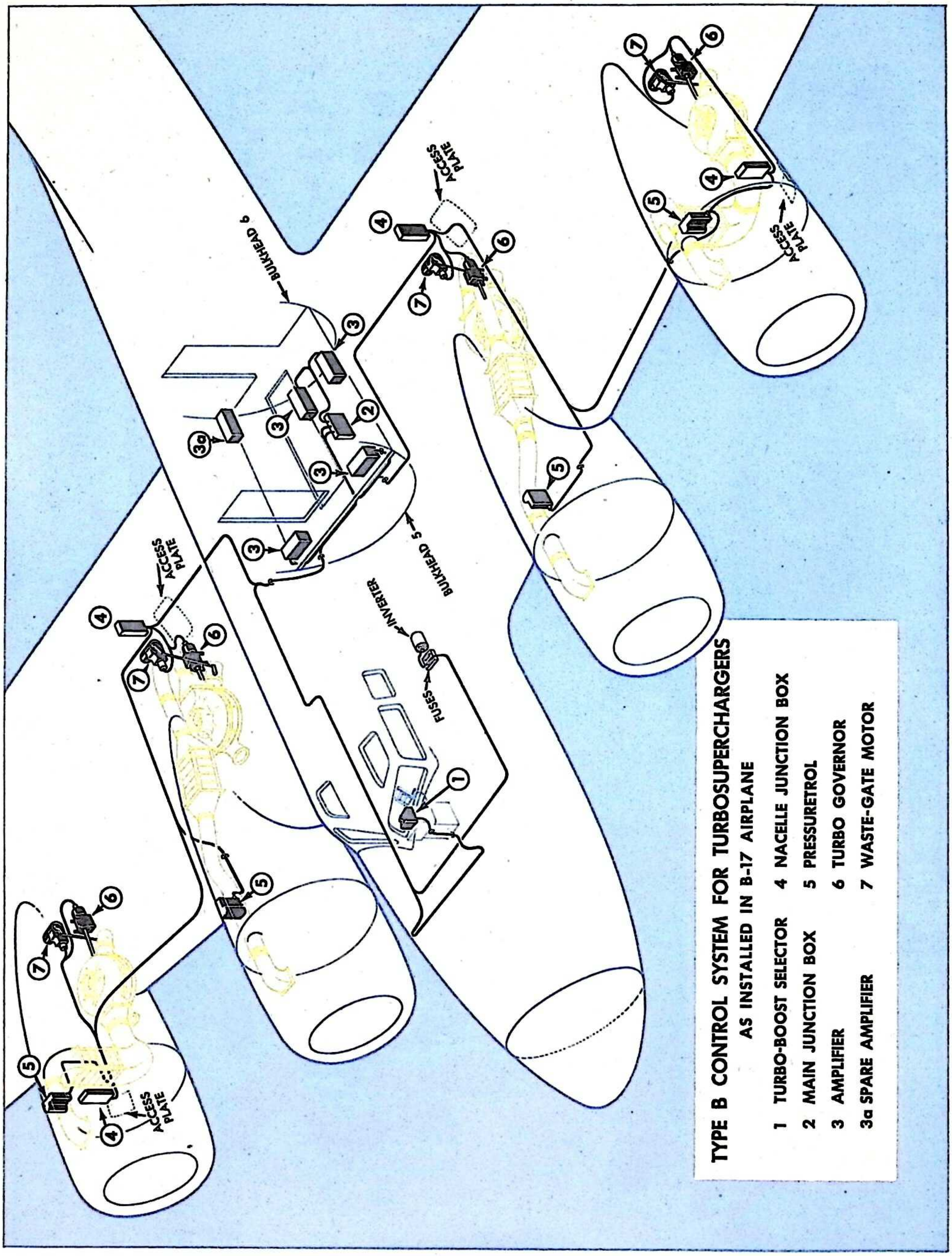


Figure 93—Complete Unit and Cable Layout Diagram for the Turbo Control System Installation in a B-17 Airplane

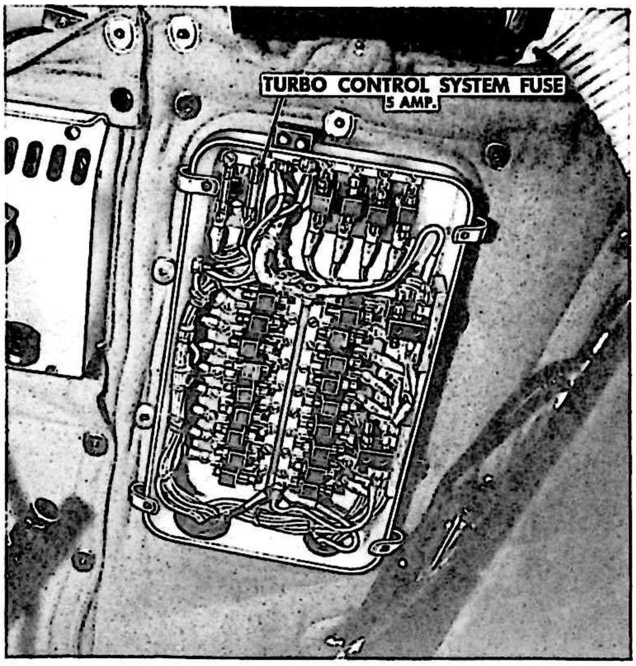


Figure 94—Copilot's Fuse Box, B-24 Airplanes

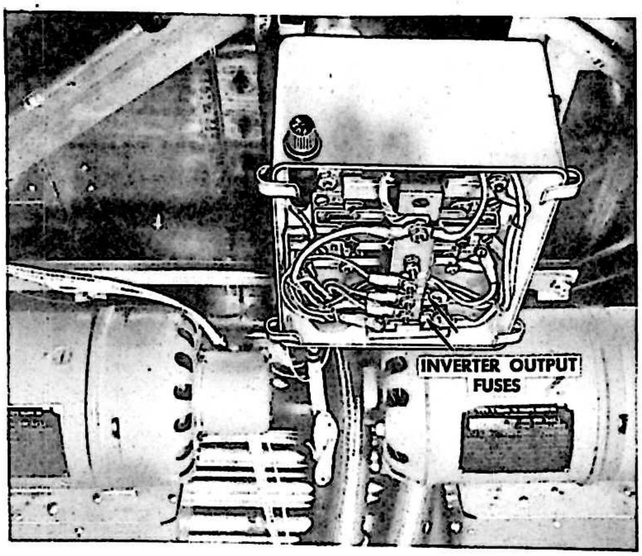


Figure 95—Special Fuses for Inverter Output, B-24 Airplanes

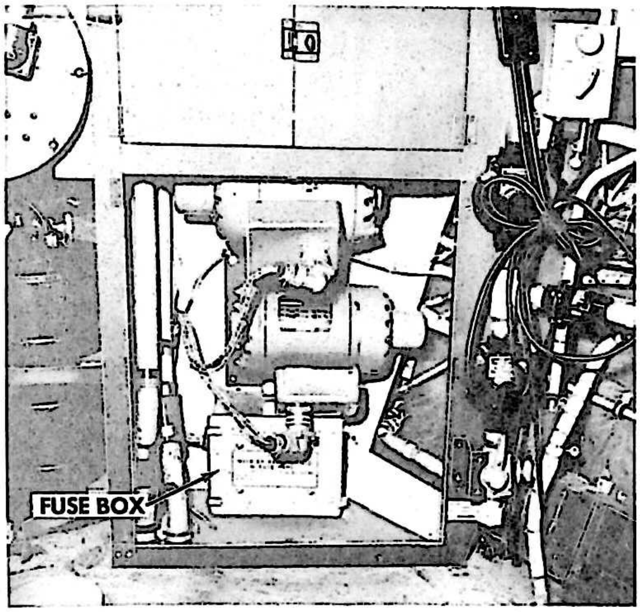


Figure 96—Inverters and Fuse Panel, B-29 Airplanes

box, which on B-17 airplanes is located directly below the cockpit on the left side of the aisle leading to the bombardier's station. On B-24 airplanes, the main fuse is in the copilot's fuse box. (See figure 94.)

The main fuse for the turbo control system is a 5-ampere fuse in the B-24 and B-29 airplanes, but a 20-ampere fuse is used in the B-17 production installations.

NOTE

In some B-24 airplanes, an additional fuse is used in the main power output line of each inverter. These fuses are installed in the inverter fuse box located beneath the floor of the radio room a short distance to the left of the inverter. (See figure 95.)

In B-29 airplanes, the main fuse box is located on the left side of the aisle at the rear of the navigator's compartment below the two inverters. (See figure 96.)

Figure 128 is a complete wiring diagram for a modification installation of a type B control system for turbosuperchargers. Refer to Installation Specification No. 28494 for approved wiring diagrams covering factory installations of turbo control systems. A wiring diagram is also inserted in the main turbo control junction box in each airplane.

After all of the units have been interconnected according to the applicable wiring diagram, inspect all the terminals and all the junction boxes to make sure washers are in place and the terminal nuts are tight. Remove any stray washers or other loose or foreign material, and check all wire numbers against the terminals to make sure all connections have been properly made. Then fasten the "J" box covers securely with the Dzus fasteners.

4. INSPECTION AFTER INSTALLATION.

To make sure all units are properly installed, perform the routine 25-hour inspection. (See section V, paragraph 2.)

5. ELECTRICAL WIRING CHECK.

a. After installation is complete, the following check should be made:

(1) Connect external power supply if available.

(2) Turn on inverter switch.

(3) Set dial of turbo-boost selector at "8."

(4) Slowly turn each calibrator clockwise until calibrator stop is reached. Waste gates should go partly closed.

(5) Turn each calibrator counterclockwise to 10 degrees past the position at which the waste gate is completely open.

b. This procedure checks the waste gate motors for correct direction of rotation. It also places the control system into approximate calibration in readiness for ground calibration and engine run-up test. If the system fails to function as outlined above, check wiring and installation details.

6. GROUND CALIBRATION.

a. The turbo control system should be calibrated to take-off manifold pressure during ground run-up following any change of calibrator settings, or when necessary following replacement of any unit in the system. It should not be necessary to recalibrate when changing grade of gasoline. The calibration should be made so that take-off pressures for 100-octane gasoline will be obtained with a dial setting of "8"; the lower manifold pressures used for 91-octane gasoline will then be obtained by stopping the dial at a point below "8."

b. It should not be necessary to change the calibrator settings during regular engine run-up procedure or preflight checks. If initial calibration is made carefully, variations in manifold pressure in regular run-up tests will then indicate malfunctions in the engine or turbo control system. To permit a more accurate check during engine run-up, avoid changing calibration settings in flight.

(1) Turn on inverter switch.

(2) Turn on filters.

(3) Start engines and turn on generators at proper rpm.

(4) Check d-c voltage. For proper calibration, the d-c voltage must be between 26 and 28.5 volts, and a-c voltage must be between 105 and 120 volts. Check a-c voltage with voltmeter attached to proper terminals in turbo control main "J" box.

(5) Proceed with regular engine run-up with dial of turbo-boost selector at "0."

(6) Set propeller governors for maximum rpm.

(7) Set turbo-boost selector at "8" (when using 100-octane gasoline).

(8) Calibrate each engine individually for take-off manifold pressure at full throttle and take-off rpm.

c. To calibrate, slowly turn calibrator clockwise, increasing manifold pressure until it reaches full take-off value if engine comes up to take-off rpm. If the engine does not come up to take-off rpm, the manifold pressure should be calibrated accordingly, approximately 1½ inches lower for each 100 rpm below take-off speed. However, if the engine fails to come within 100 rpm of take-off rpm, locate and remedy the cause of this engine malfunction before further calibration is attempted.

NOTE

Calibrating should be done when using 100-octane gasoline if possible. If it is necessary to calibrate when using 91-octane gasoline, use the following dial settings and calibrate to the proper take-off pressure for the fuel being used.

AIRPLANE	B-17	B-24
Take-off dial setting for 91-octane gasoline	7	6
Take-off pressure for 91-octane gasoline .	43.5 in. Hg*	42.7 in. Hg*

*Refer to T.O. No. 02-1-38 for take-off manifold pressures used with alternate grade fuels.

7. OPERATION CHECK.

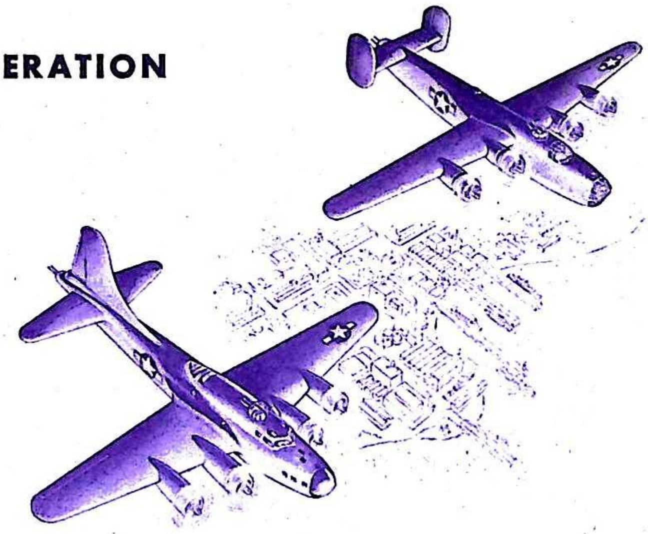
To make sure all units function properly, perform the routine engine run-up procedure. (See section IV, paragraph 2 *b.*)

8. TROUBLESHOOTING.

If any malfunction is noted in preceding checks, remove the cause of the malfunction, or, if the cause is unknown, perform the troubleshooting procedure outlined in section V, paragraph 5 *a.*

Section IV

OPERATION



1. PRINCIPLES OF OPERATION.

a. GENERAL.

(1) The potentiometers in the control units—turbo-boost selector, turbo governor, and Pressuretrol—are interconnected with the balancing potentiometer in the waste-gate motor to form an electrical "bridge" circuit.

(2) Whenever the wiper on one or more of the potentiometers in the control units is moved, it produces an a-c signal calling either for clockwise or counterclockwise rotation of the waste-gate motor. Clockwise signals are represented in the accompanying illustrations by red lines; the counterclockwise signals by blue lines. (See figures 97 and 99.) Actually, the two types of signals differ in electrical characteristics, as explained in the following paragraphs.

(3) The signals, originating at the control units, are amplified by the amplifier and transmitted to the waste-gate motor, producing the required waste-gate movement.

(4) When the waste-gate motor is made to rotate clockwise by a "red" signal from the control units, as shown in figure 97, this rotation causes the potentiometer in the waste-gate motor to feed a "blue" signal into the amplifier, neutralizing the "red" signal which caused the motor's rotation. When the waste-gate motor signal is equal (but opposite) to the control signal, the signal is balanced out and rotation of the waste-gate motor stops. (See figure 98.)

(5) When any of the control units produces a "blue" signal, the resulting rotation of the waste-

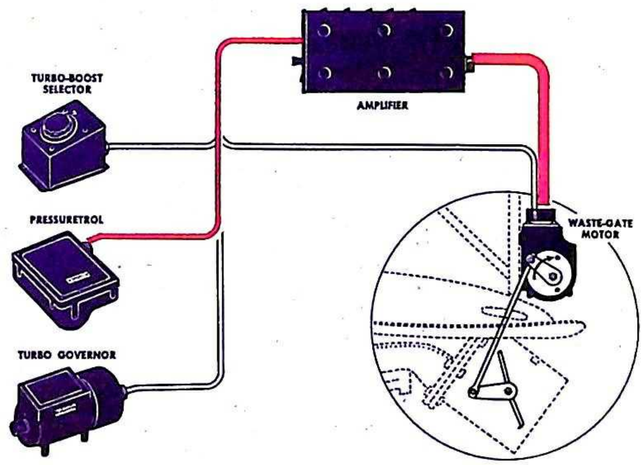


Figure 97—Control Units Call for Closed Waste Gate With "Red" Signal to Amplifier

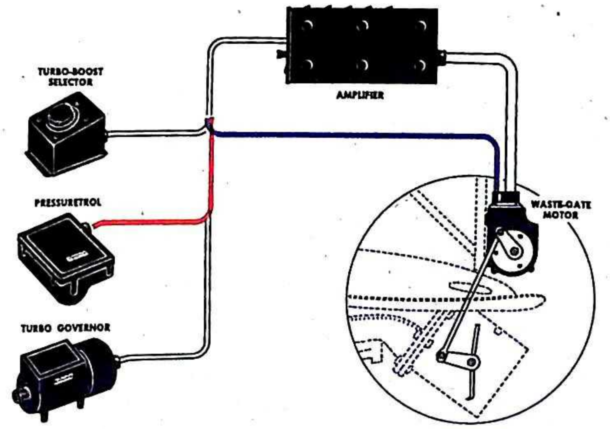


Figure 98—Resulting Rotation of Waste-Gate Motor Produces Balancing "Blue" Signal and Rotation Stops

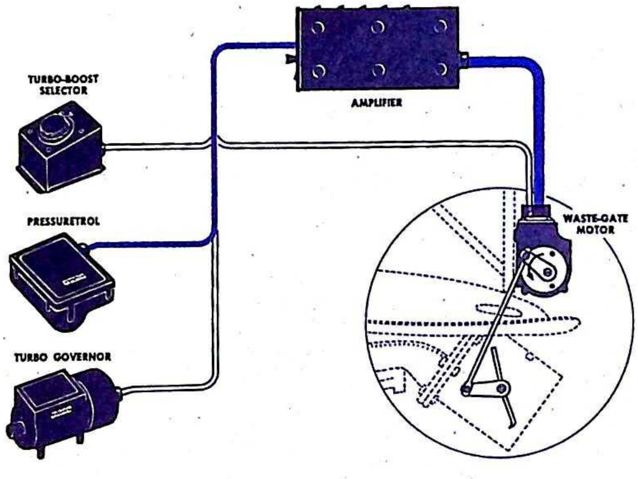


Figure 99—Control Units Call for Open Waste Gate With "Blue" Signal to Amplifier

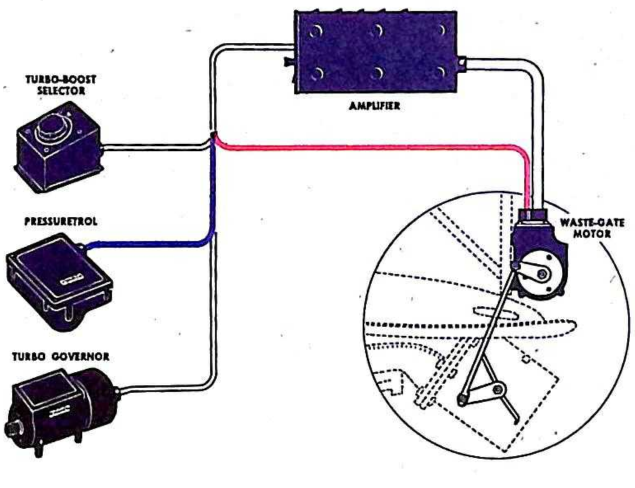


Figure 100—Resulting Rotation of Waste-Gate Motor Produces Balancing "Red" Signal and Rotation Stops

gate motor is counterclockwise. The balancing signal produced this time by the waste-gate-motor potentiometer is a "red" signal which neutralizes the control signal when the waste gate has moved the required amount. (See figures 99 and 100.)

(6) The following paragraphs give a more complete and detailed explanation of the electrical operation of the control units and their interrelation.

b. THEORY OF THE BRIDGE SYSTEM.

(1) The principle by which the control units in the turbosupercharger control system govern the position of the waste gate is based on the operation of a simple control bridge circuit.

(2) The simplest type of a-c bridge circuit is shown in figure 101. It consists of a coil of fine wire with two sliding contacts which may be moved independently to any point on the coil. An a-c voltage is applied across the coil by the secondary winding of a transformer.

(3) For purposes of explanation, both contacts or wipers are positioned at the center of the coil, and the lower wiper is connected to ground.

(4) As alternating current is made to flow through the coil by the transformer, the two ends of the coil become alternately positive and negative with respect to the grounded wiper. But at any instant when the right end of the coil is positive, the left end is negative, and vice versa. The fluctuations in the voltages of the two ends of the coil during one cycle (1/400 second) are indicated by the graphs in figure 102. In these graphs, the voltage of the right end of the coil is represented by the red curve; the voltage of the left end by the blue curve.

(5) When the two wipers contact the same point on the coil, as shown in figure 101, they are at the same potential (ground potential in this illustration). Under these conditions the bridge is "in balance."

(6) However, when the upper wiper is moved toward the left (as in figure 103), its potential will fluctuate in phase (or in step) with the left end of the coil. The size or amplitude of its voltage fluctuations with respect to the grounded wiper will be directly proportional to the distance it has moved from the grounded wiper. The bridge is now "unbalanced."

(7) On the other hand, if the upper wiper is moved toward the right (as in figure 104), its potential will fluctuate in phase with the right end of the coil. Again the amplitude of its voltage fluctuations, or

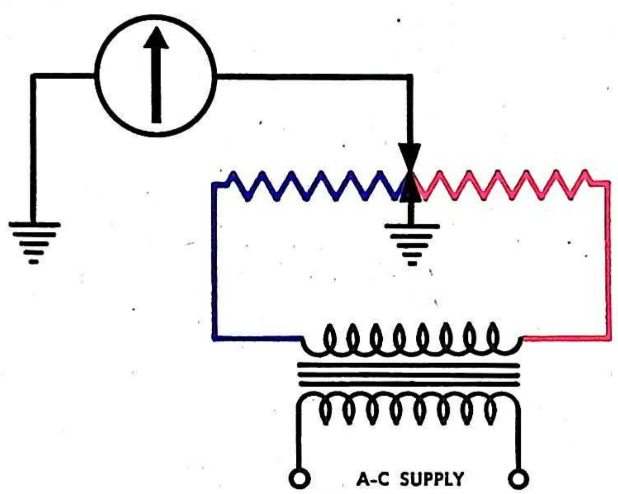


Figure 101—Simple Bridge Circuit (in Balance)

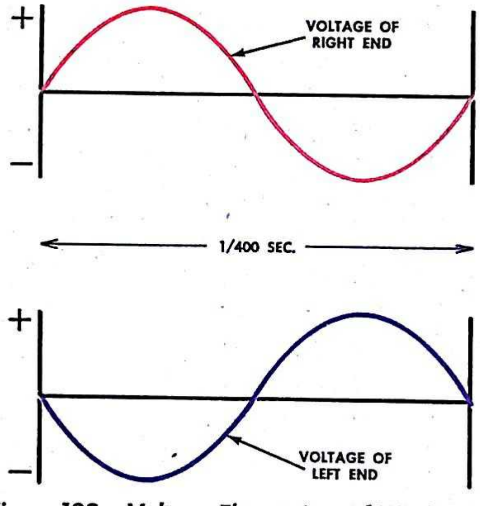


Figure 102—Voltage Fluctuations of Winding Ends With Respect to Grounded Wiper

signal, will be proportional to its displacement from the grounded wiper.

(8) It is apparent that when the wipers are displaced (figure 104), producing an a-c signal at the upper wiper, this signal may be reduced and finally eliminated (bridge rebalanced) in either of two ways: the upper wiper may be returned to the position of the lower wiper, *or* the lower wiper may be moved to the position of the upper one. (See figure 105.)

(9) Likewise, when the bridge is unbalanced by movement of the lower wiper, it may be rebalanced by moving either wiper to the position of the other.

(10) A bridge of the type shown in figures 101 to 105 is impractical for many control applications because in control applications the wipers must be connected to different units which are widely sep-

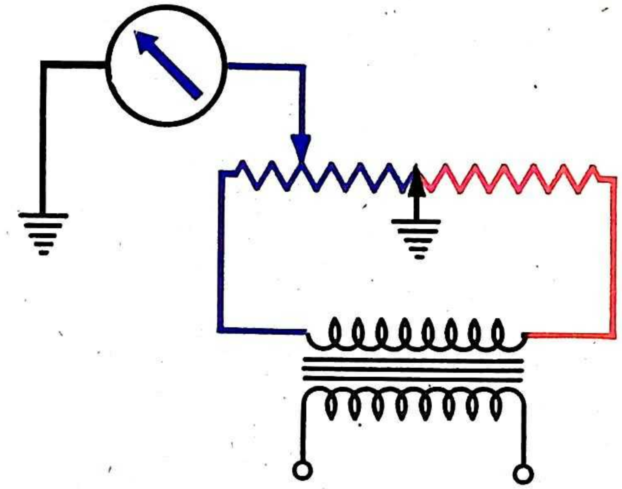


Figure 103—Unbalanced Bridge Producing Signal in Phase With Left End of Winding

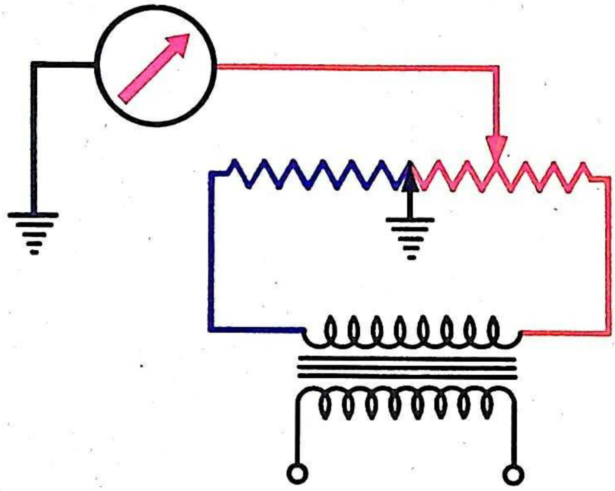


Figure 104—Unbalanced Bridge Producing Signal in Phase With Right End of Winding

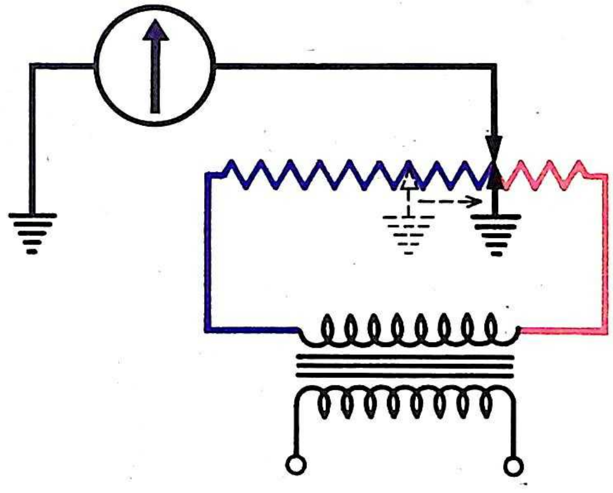


Figure 105—Bridge Rebalanced by Moving Grounded Wiper

arated and therefore cannot be made to contact the same coil of wire. For such applications, a separate coil is used for each wiper, and the two coils are connected in parallel, as shown in figure 106. Each coil with its wiper is called a potentiometer.

(11) When two potentiometers are connected in parallel, their electrical characteristics are identical. For every point on one potentiometer winding, there is a corresponding point of the same potential on the other winding. Consequently, the bridge is unbalanced (signal produced at upper wiper) by movement of either wiper; and it is rebalanced by moving either wiper until both are again at points of equal potential.

(12) Sometimes, for design reasons, one potentiometer is operated on a lower voltage than the other. In such cases, the lower voltage potentiometer is connected across only a part of the transformer winding, as shown in figure 107. A bridge of this kind operates exactly the same as a symmetrical bridge except that the amount of signal change produced by moving the low-voltage wiper from one extreme to the other is reduced. Also, note that if the high-voltage wiper in the illustration is moved onto the left half of its winding, the bridge cannot be balanced by moving the low-voltage wiper because there is no portion of the low-voltage winding which corresponds to the left half of the high-voltage winding.

(13) Figure 108 is a schematic representation of the complete bridge system employed in the type B control system for turbosuperchargers. Note that between the potentiometer wiper of the turbo-boost selector and the waste-gate potentiometer wiper there are three simple bridges connected in series. In this illustration, the wipers are shown at typical positions for purposes of explanation.

(*a*) Considering only the bottom bridge made up of the potentiometer in the turbo-boost selector and a calibrator potentiometer, note that the signal produced between the two wipers is three volts and that it is in phase with the right end of the potentiometers. This signal therefore is arbitrarily called a "red" signal of three volts. If such a signal were applied directly to the grid of the amplifier, it would produce rotation of the waste-gate motor in the direction required to *open* the waste gate.

(*b*) Considering the Pressuretrol–accelerometer bridge, note that the signal produced between the two wipers is a "blue" signal of 15 volts. Since this signal is 180 degrees out of phase (out of step) with the signal from the lower bridge, the net effect of the two signals is equal to 15 – 3 or a blue signal of 12 volts.

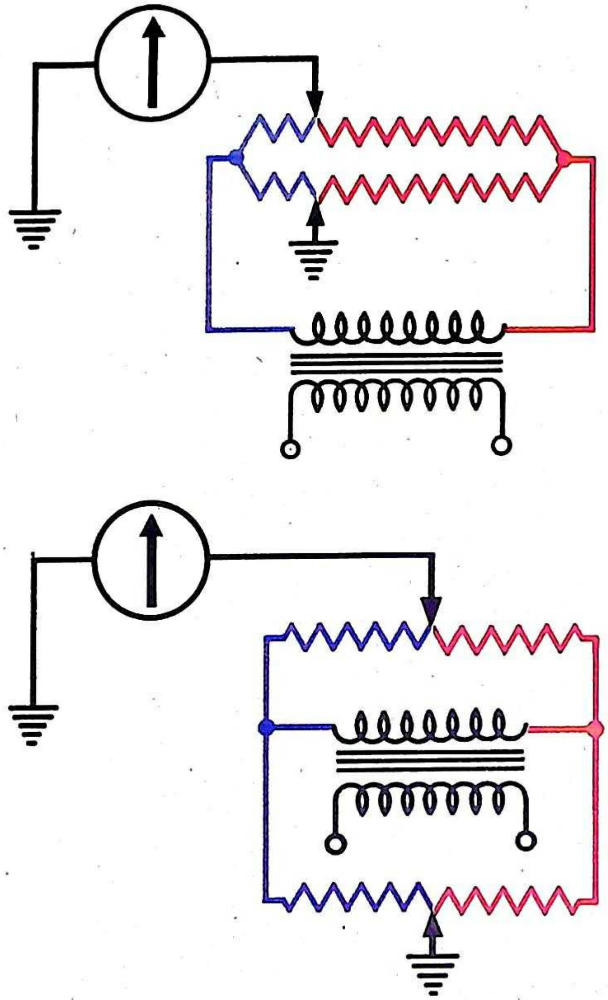


Figure 106—Two Diagrams of a Bridge Formed by Two Potentiometer Windings in Parallel

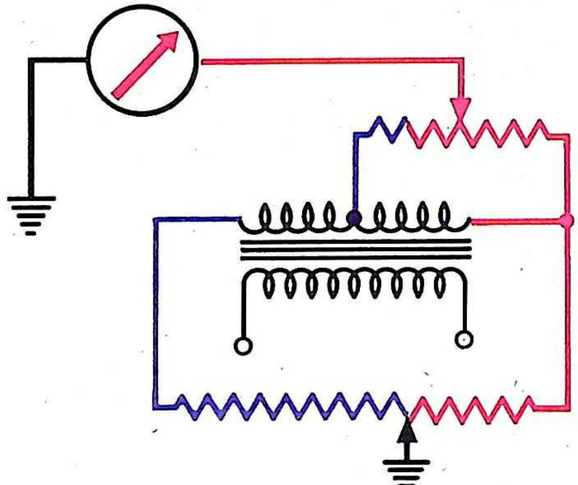


Figure 107—Simple Bridge With One Low-Voltage Winding

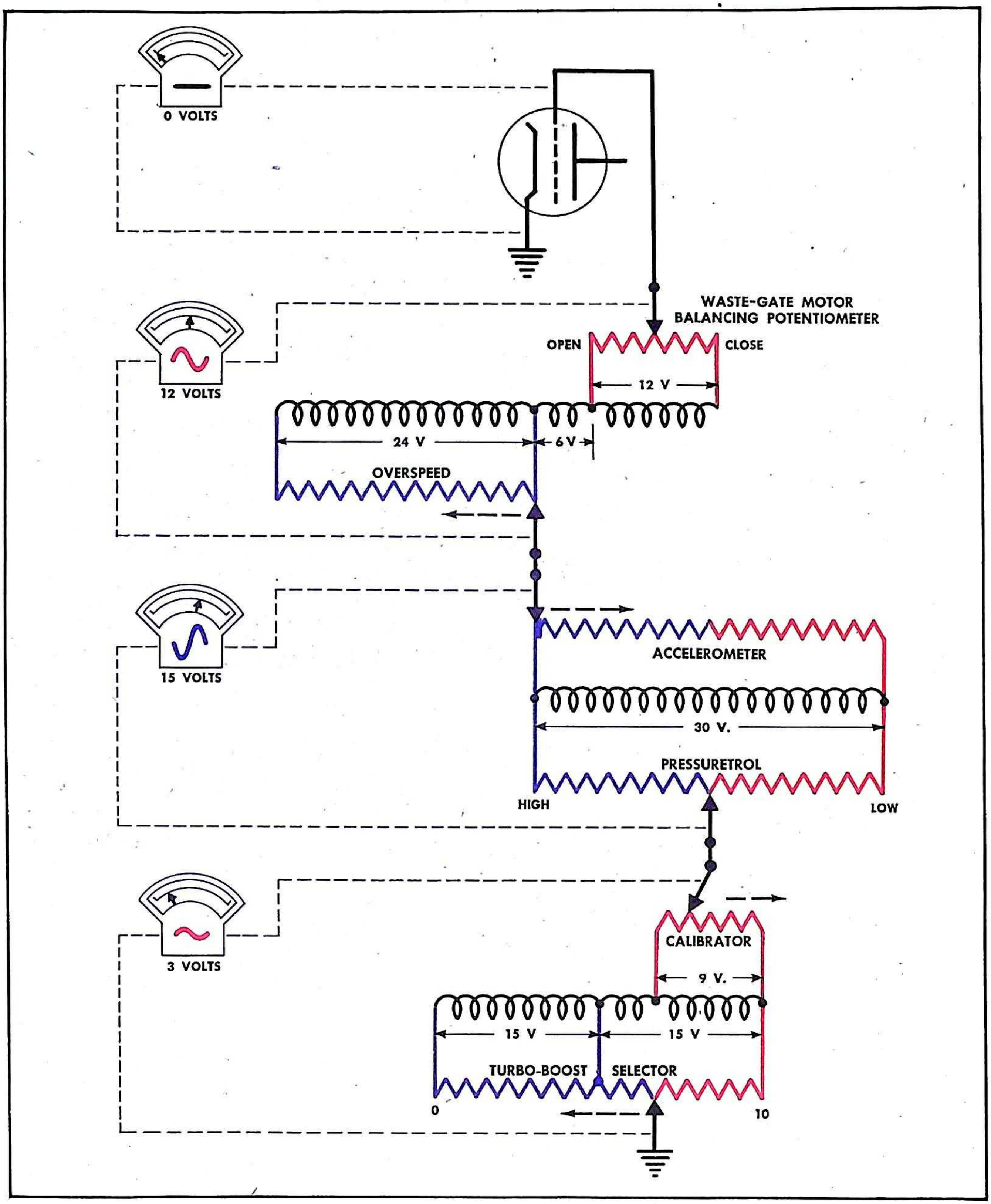


Figure 108—Complete Bridge Circuit of the Type B Control System for Turbosuperchargers

(*c*) The overspeed–balancing potentiometer bridge, on the other hand, produces a "red" signal of 12 volts, which opposes the 12-volt "blue" signal from the two lower bridges. Therefore, since the sum of the "blue" signals is equal to the sum of the "red" signals, the two signals exactly neutralize each other. Under these conditions, no voltage signal is applied to a voltmeter connected between the balancing potentiometer wiper and ground, and the entire bridge circuit is balanced even though the individual bridges are unbalanced.

c. OPERATION OF THE BRIDGE SYSTEM.

(1) As explained in paragraph *b* (13), when the red and blue signals of all the bridges neutralize each other, the bridge is in balance, and the movement of either wiper of the lower bridge in the direction of the dotted arrow produces an increasing "red" signal or a decreasing "blue" signal, either of which will unbalance the bridge. When the bridge is unbalanced by movement of the wiper in the direction indicated, the "red" signal will predominate and cause the waste gate to move toward the open position. It can be seen that when the waste gate opens in response to a "red" signal, the motor wiper is moved toward the left, reducing the "red" signal which caused the rotation. When this decrease is equal to the change in the signal from the bottom bridge, the system is again balanced and the waste gate remains in its new position. Opposite movement of either wiper in the lower bridge would have an opposite effect. Thus the position of the waste gate can be regulated by operating the potentiometer of the turbo-boost selector.

(2) A similar response is produced by movement of either wiper in the middle bridge, which includes the Pressuretrol and accelerometer potentiometers. The wiper of the Pressuretrol potentiometer moves toward the left when carburetor deck pressure increases and toward the right when carburetor deck pressure decreases. Thus, when the carburetor deck pressure drops below the desired value, the Pressuretrol potentiometer wiper moves to the right, producing an increase in the "blue" signal from this bridge. This movement will continue until the "red" signal produced by the top bridge is increased sufficiently to cancel out the increased "blue" signal produced by the movement of the Pressuretrol potentiometer wiper.

NOTE

In the airplane, this movement of the waste gate in response to a "blue" signal from the Pressuretrol results in an immediate increase in carburetor deck pressure. This increased pressure causes the Pressuretrol wiper to move to the left, canceling most of its original "blue" signal. However, the waste gate will still be moved slightly toward "close," and the total bridge will be balanced with the pressure just below the value set by the turbo-boost selector. For a more complete explanation of this action, known as the system "droop," see section IV, paragraph *f.*

(3) If the acceleration of the turbosupercharger is rapid, the accelerometer potentiometer wiper will move to the right, reducing the "blue" signal produced by the Pressuretrol (see paragraph (2) preceding). This will cause the waste gate to move toward the open position unless the Pressuretrol signal is still of sufficient strength to hold the waste gate closed. The accelerometer is therefore an anticipator which acts to open the waste gate slightly ahead of the time the Pressuretrol alone could open the gate, and by so doing eliminates overshooting. It does not and cannot limit the acceleration obtainable with a closed waste gate.

(4) Referring to the overspeed control potentiometer in the top bridge, it is apparent that any movement of the overspeed wiper to the left (resulting from operation of the turbo at excessive speeds) will increase the "red" signal applied to the amplifier and cause the waste gate to open. This, in turn, will cause the turbine to slow down, and overspeed will be prevented.

(5) As explained previously, opening the waste gate causes the turbo to slow down. Therefore, the dotted arrows in figure 108 not only indicate the direction each wiper must move to open the waste gate, but also the proper direction for decreasing turbo boost.

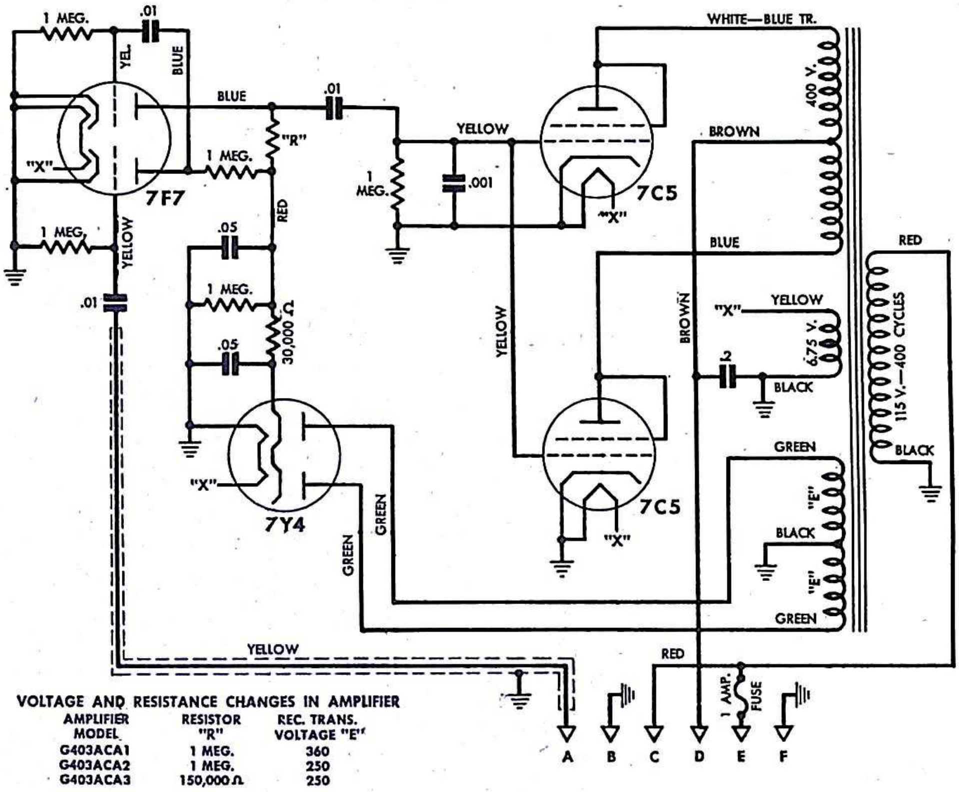
(6) In this explanation, the movement of only one wiper at a time has been considered. In actual operation, however, two or more control wipers will be affected by any unbalance in the bridge circuit. Suppose, for example, that with the bridge in a balanced condition as shown, the turbo-boost selector is turned to a higher setting (potentiometer moved to the right). The signal produced will cause the waste gate to move toward the closed position, causing an increase in carburetor intake pressure. The Pressuretrol will detect this increased pressure, and the wiper of the Pressuretrol potentiometer will move toward the high-pressure end of the potentiometer winding. This movement will signal the waste gate to open slightly. A new condition of balance will then exist

in which the waste gate is somewhat more closed and the carburetor intake pressure is somewhat higher than before the turbo-boost selector setting was increased. Thus, the movement of one wiper in the system may result in movement of one or more other wipers to produce a new condition of balance.

d. OPERATION OF THE AMPLIFIER.

(1) GENERAL.

(*a*) Figure 109 is a schematic wiring diagram of the complete turbo control amplifier. The tubes are all of the heater type, a-c heater voltage being sup-



VOLTAGE AND RESISTANCE CHANGES IN AMPLIFIER

AMPLIFIER MODEL	RESISTOR "R"	REC. TRANS. VOLTAGE "E"
G403ACA1	1 MEG.	360
G403ACA2	1 MEG.	250
G403ACA3	150,000 Ω	250

Figure 109—Schematic Wiring Diagram of Turbo Control Amplifier

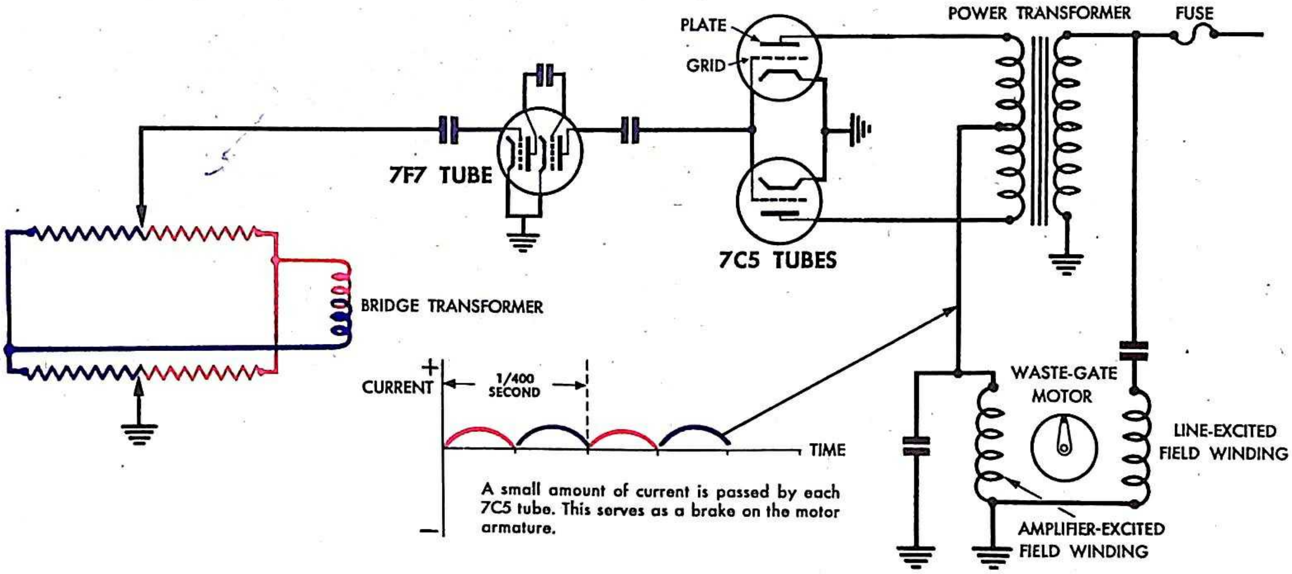


Figure 110—Schematic Drawing of Bridge System, Amplifier, and Waste-Gate Motor Circuits—Bridge Balanced

plied by a secondary winding on the amplifier transformer. The rectifier (7Y4) circuit supplies a high d-c voltage to the two plates of the 7F7 tube. The two plates of the 7C5 tubes are connected to opposite ends of the same transformer winding. The power output resulting from amplifier operation is directed to one field winding of the waste-gate motor through terminal D of the AN connector. The power for the other field winding in the motor is delivered direct from the 115-volt input line through a 1-ampere fuse and AN-connector terminal E.

(*b*) In the following explanation and accompanying illustrations only those elements of the system are included which are necessary for tracing a signal from the bridge system, through the amplifier to the waste-gate motor.

(*c*) The complete bridge system is represented in the illustrations as a single bridge from which the two types of signals are sent to the amplifier.

(*d*) The signals from the bridge are conducted to the 7F7 tube, which first increases their strength, and then transmits them to the grids of the 7C5 tubes. These tubes discriminate between signals calling for the waste gate to open and those calling for it to close.

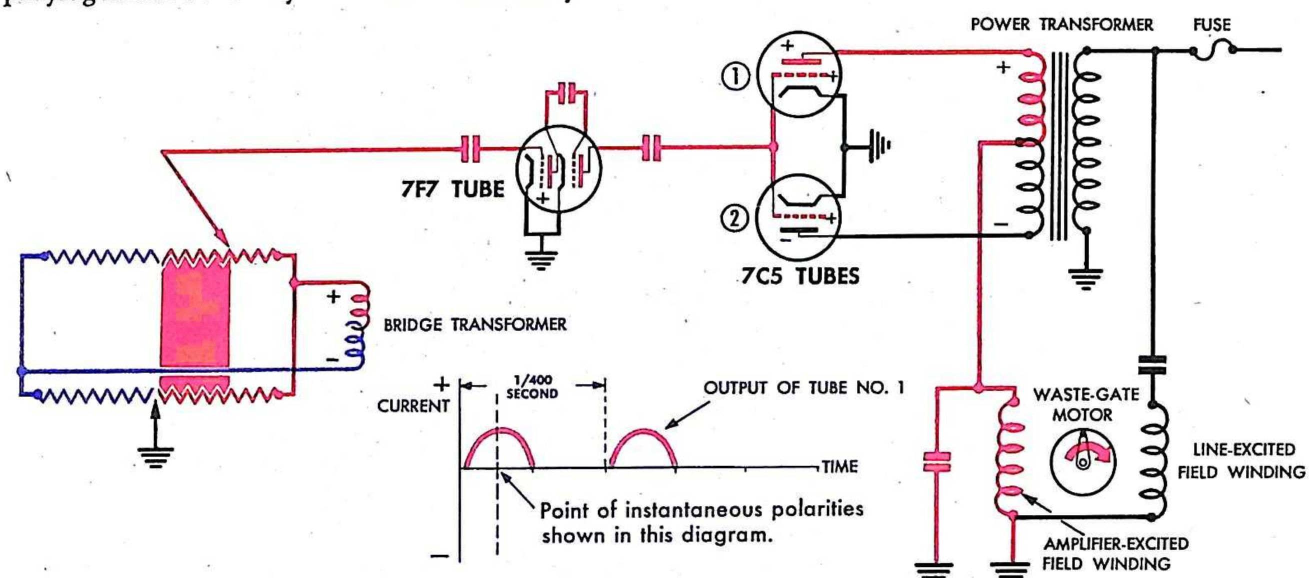


Figure 111—Positive Red Signal From Bridge, No. 1 Tube Operating

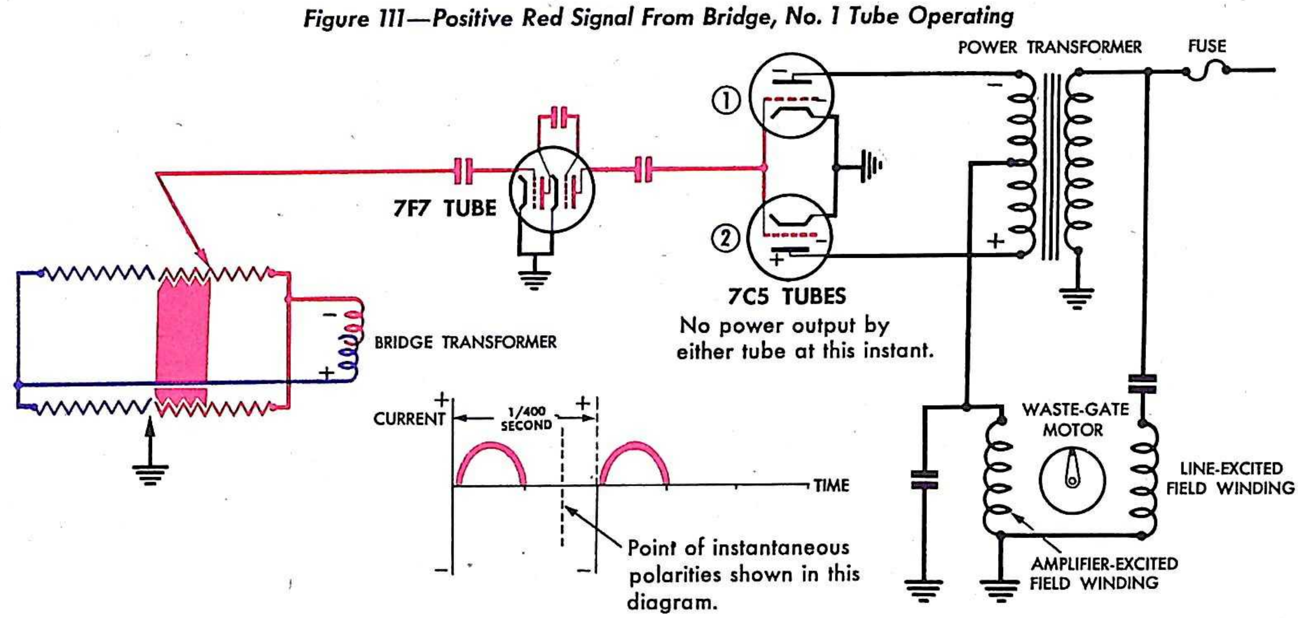


Figure 112—Negative Red Signal From Bridge, Neither Tube Operating

(*e*) Since the two plates of the 7C5 tubes are connected to opposite ends of the same transformer winding, they are always of opposite polarity. When one plate is positive, the other plate is negative, and vice versa. (See figure 110.)

(*f*) The transformer that supplies the voltage for the bridge is "in phase" with the transformer that supplies the plate voltage for the 7C5 tubes. (When two transformers are in phase, the corresponding ends of each transformer become positive at the same instant.) Therefore the plate of tube No. 1 is always of the same polarity as the right end of the bridge.

(*g*) In the illustrations following figure 109, the rectifier circuit, including the 7Y4 tube, is omitted because it does not enter into the explanation of the signal travel through the amplifier.

(*h*) The resistors and some of the condensers are also omitted for the sake of simplicity. The rectifier circuit, resistors, and condensers are all essential for operation of a complete amplifier, but their exact use and the values of these elements are matters of design and are not discussed in this explanation. The curves included with each illustration represent the amplifier current output resulting from the bridge unbalance shown in the electrical diagram.

(2) THE BRIDGE SIGNAL AND THE DISCRIMINATOR ACTION OF THE 7C5 TUBES IN THE AMPLIFIER.

(*a*) In figure 110, the bridge is shown in a "balanced" condition with no signal going to the amplifier. In figure 111, the bridge is unbalanced by movement of the wiper to one side of the potentiometer winding. The plus and minus signs show the polarities at an instant when the upper ends of the two transformers are positive, the same as in figure 110. Since the upper end of the power transformer is positive, the plate of the upper (No. 1) 7C5 tube is also positive at that instant.

(*b*) The grid in the tube controls the flow of electrons from the cathode to the plate. When the plate of a tube is positive, it will attract electrons (which are negative). When the grid is also positive, it aids the flow of electrons to the plate; but when the grid is a strong negative, it stops the flow of electrons even though the plate is positive. When the plate is negative no current will flow through the tube regardless of the grid polarity.

(*c*) In figure 111, the grid and the plate in tube No. 1 are both positive; therefore, current (electrons) flows in that tube. In tube No. 2, the grid is positive but the plate is negative; consequently, no current flows in tube No. 2. Thus the signal coming from the bridge is in phase with the plate voltage on No. 1 tube, and No. 1 tube is supplying the power to the motor field winding. For the purpose of illustration, assume that the motor rotates clockwise when the power comes from No. 1 tube.

(*d*) Figure 112 is exactly the same as figure 111, except that it represents a condition 1/800 second later and the current in both transformers has reversed. (Power supply is 400-cycle alternating current.) This means that the bridge signal has become negative, making the grids of both tubes negative.

(*e*) At the same instant, the plate on No. 1 tube is negative, while the plate on No. 2 tube is positive; since the grid of both tubes is *negative,* no current will flow in either tube. Therefore, at the instant illustrated (figure 112) no power is flowing from the amplifier to the motor. One eight-hundredth of a second later, the polarities are back to the same condition shown in figure 111, and No. 1 tube is again functioning.

(*f*) From figures 111 and 112 it can be concluded that, when the wiper is at the right end of the potentiometer winding in the single bridge, the signal voltage is in phase with the plate voltage of tube No. 1 and only this tube operates, driving the motor *clockwise.*

(*g*) The power output from one tube consists of positive impulses only, as illustrated by the voltage output curves accompanying each diagram.

(*h*) Figure 113 shows the same instantaneous polarity on the transformers as in figure 111. However, the potentiometer wiper has been moved to the left end of the winding and is picking up a negative voltage at the instant illustrated; therefore, the grids of the 7C5 tubes are both negative. The plate of No. 1 tube is positive, as in figure 111, but no current will flow because the grid is negative; likewise no current flows in No. 2 tube because both grid and plate are negative. At this instant, then, no power is being delivered to the motor by either tube in the amplifier.

(*i*) Figure 114 is the same as figure 113 except that the condition represented is one-half cycle later, causing all polarities to be reversed. Thus the conditions of polarity set up in figure 114 are the same as in figure 112 with the exception of the position of the potentiometer wiper. With the wiper at the left end of the potentiometer winding, it is picking up a *positive* voltage at this instant, thereby making

the grids of both 7C5 tubes positive. The plate of tube No. 1 is now negative; therefore, it does not conduct current. But the plate of tube No. 2 is positive; therefore current flows through tube No. 2.

(*j*) From figure 114, it is apparent that No. 2 tube will operate only when the wiper is at the left end of the potentiometer winding, producing a signal in phase with the voltage at the plate of tube No. 2. The power is being delivered to the motor in impulses coming 1/800 second (½ cycle) later than those delivered by No. 1 tube (figure 110); therefore, the motor rotates *counterclockwise.*

(*k*) As explained in the preceding paragraphs, the output of the 7C5 tubes consists of positive impulses with a time interval between each impulse. For proper operation of the waste-gate motor, however, it is necessary to have alternating current flow through the amplifier-excited winding instead of the d-c impulses. Therefore, a condenser of the proper size is connected in parallel with the field winding to form an oscillating circuit. The current in the condenser and field winding oscillates back and forth in a manner similar to the swinging of a pendulum, and the impulses from the amplifier supply the power to start and to maintain this oscillating circuit.

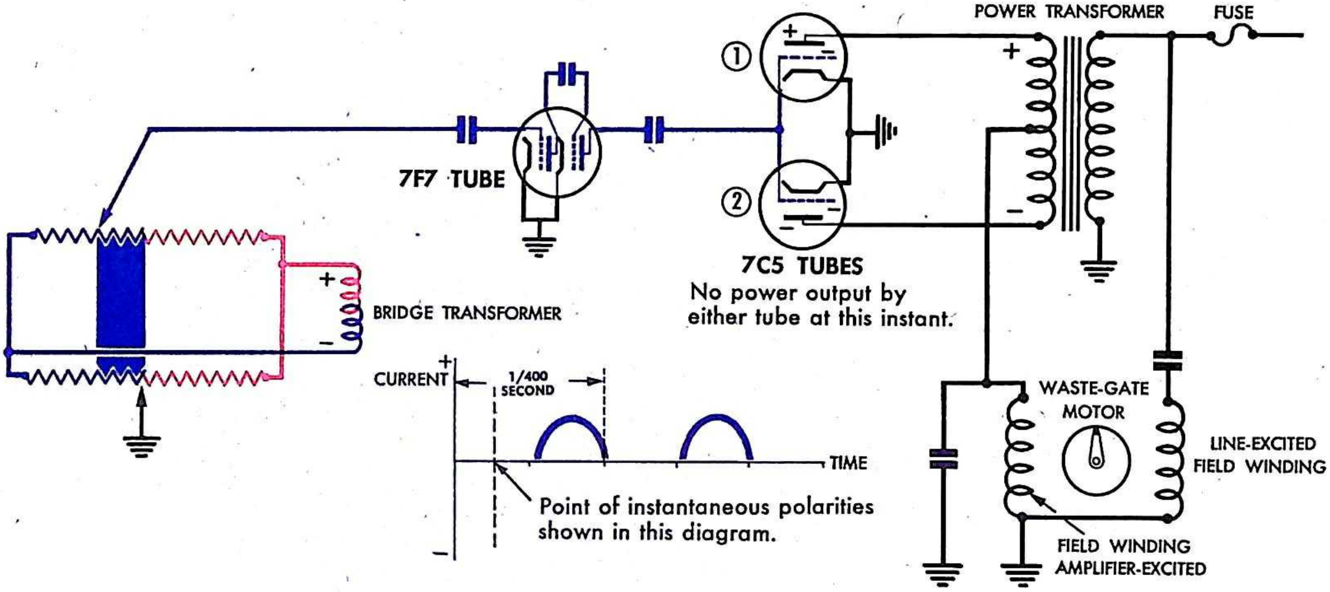


Figure 113—Negative Blue Signal From Bridge, Neither Tube Operating

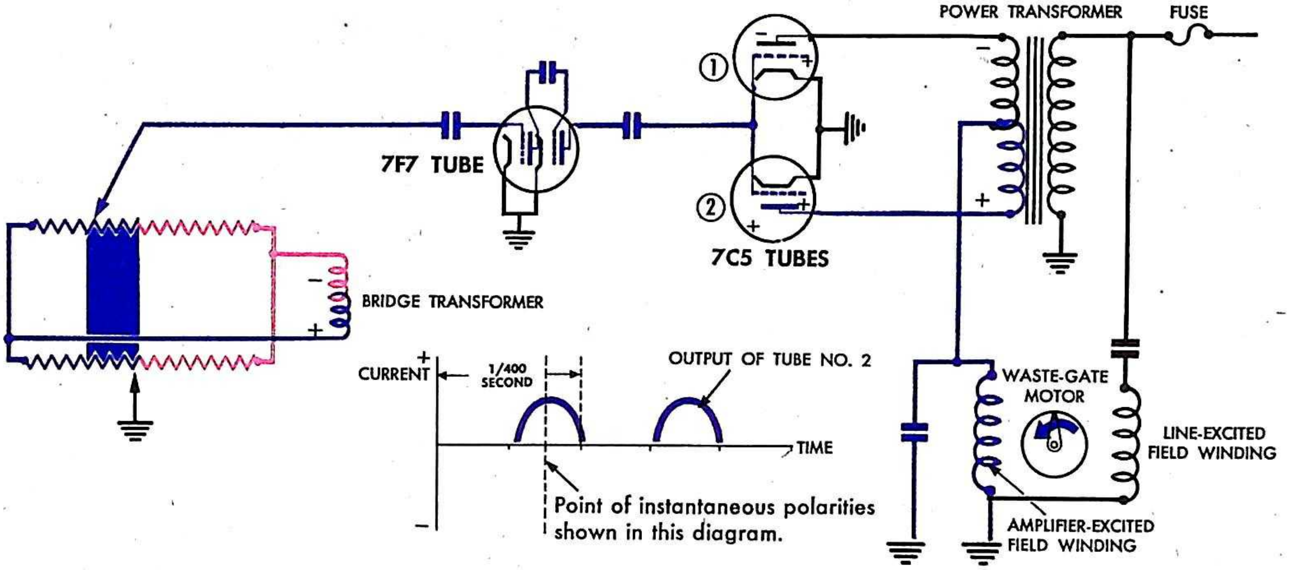


Figure 114—Positive Blue Signal From Bridge, No. 2 Tube Operating

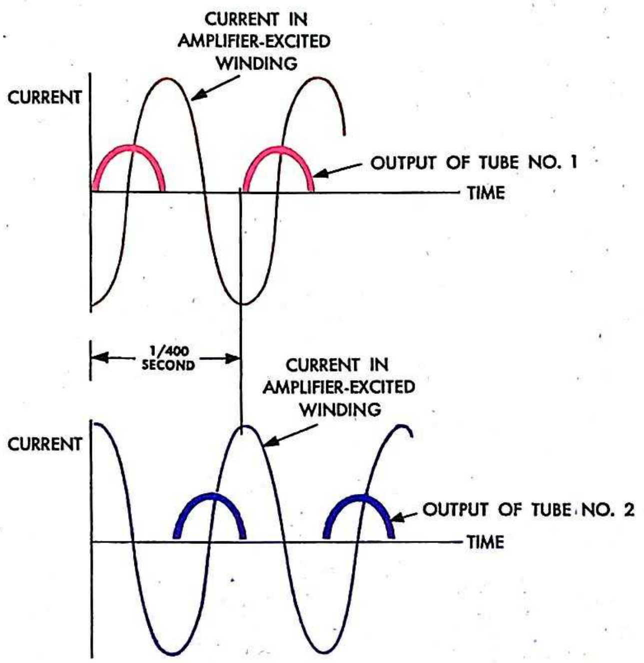


Figure 115—Curves Representing Currents in Amplifier Phase of Motor

(*l*) The relationship between current flow through the 7C5 tubes and through the amplifier-excited winding of the waste-gate motor is shown in figure 115. Note that the current resulting from operation of one tube is ½ cycle out of phase with the current resulting from operation of the other tube.

e. OPERATION OF THE WASTE-GATE MOTOR.—The following explanation covers the general theory of operation of a two-phase motor. This theory is then applied specifically to the operation of the waste-gate motor.

(1) TWO-PHASE MOTOR OPERATION.

(*a*) The force which drives an induction-type a-c motor (or so-called "squirrel-cage" motor) is produced by magnetic attraction and repulsion between a series of electromagnets called the stator, and a rotating part called the rotor. To understand the magnetic forces involved, the fundamental laws of magnetism should first be considered.

(*b*) A magnet has two "poles," "north" and "south." An "electromagnet" is a piece of soft iron with a coil wound around it. When current flows through this coil, it magnetizes the iron core, giving the core a north pole at one end and a south pole at the other. Reversing the direction of current flow through the coil reverses the polarity of the iron.

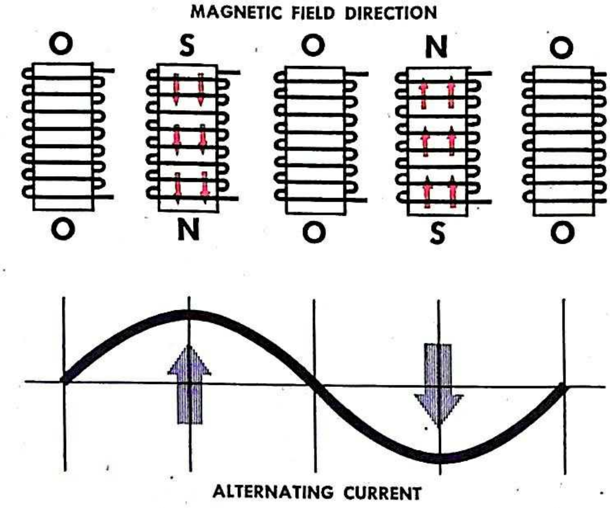


Figure 116—Magnetic Polarities Vary With Changes in Direction of Current

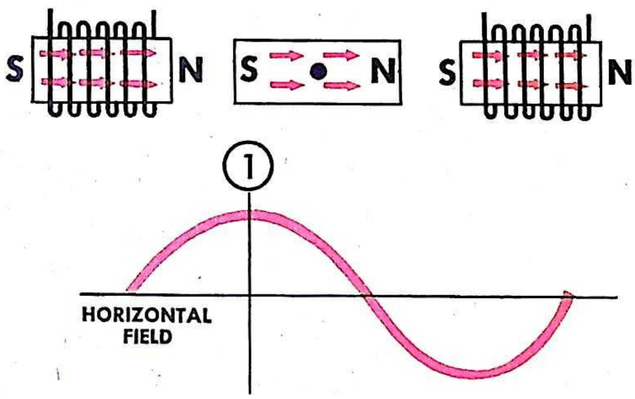


Figure 117—Magnetic Poles Induced in a Rotor Bar by Two Stator Poles

(*c*) If alternating current is used to energize the coil, the magnetic field of the electromagnet will rise from zero to a high strength of one polarity, then decline to zero and build up to a high value of the opposite polarity, following corresponding changes in value of the alternating current. (See figure 116.) The electromagnets which operate an induction-type a-c motor are energized in this manner.

(*d*) If an iron bar, pivoted in the center, is placed between two electromagnets arranged so that their inner ends are of opposite polarity, the iron bar receives an "induced" magnetism. (The bar may be considered a "rotor," with the inner ends of the electromagnets forming the "stator.") The induced magnetism produces poles in the bar which are opposite to the electromagnetic poles nearest them. (See figure 117.) If the electromagnets are energized by alternating current, their magnetic fields will be con-

stantly reversing and the induced polarity of the iron bar will tend to follow this reversal. The magnetic poles found in the rotor of an a-c induction-type motor are induced poles formed in this manner.

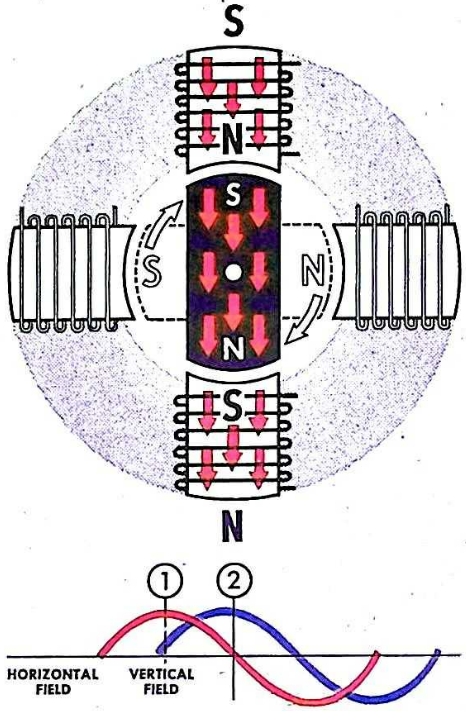


Figure 118—Rotation Produced by Two Out-of-Phase Magnetic Fields at Right Angles

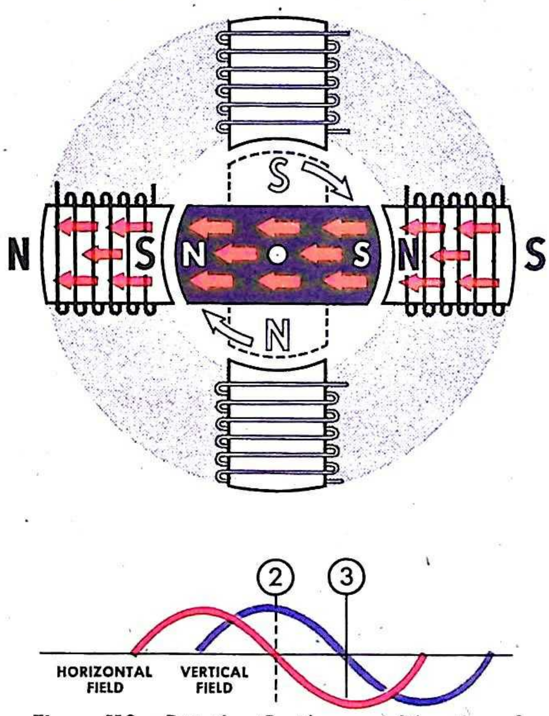


Figure 119—Rotation Continues as Direction of Horizontal Field Is Reversed

(*e*) When only two stator poles are present, as in figure 117, the rotor bar will be stationary. However, if two more electromagnets are introduced (as in figure 118) with a magnetic field which becomes maximum when the horizontal field becomes zero, the rotor bar will turn on its pivot as it tries to align itself with the two poles of strongest polarity.

(*f*) In figure 117, the rotor bar is held horizontal by the magnetic attraction of the two poles. When the alternating current through these two coils dies down rapidly, the induced magnetism in the rotor bar will also die down, but more slowly. If the time relationship of the current in the two vertical poles of figure 118 is such that it rises to a maximum as the current in the horizontal poles dies down to zero (¼-cycle phase difference), there will be a strong vertical magnetic field acting on the rotor bar while this bar still retains its magnetism. The north pole of the bar will be attracted by the stator south pole and repelled by the stator north pole. Therefore, the bar will turn about its pivot, as shown in figure 118.

(*g*) When the vertical magnetic field dies down in turn, the horizontal field will again be building up. However, since these electromagnets are energized by alternating current, the current will now be flow-

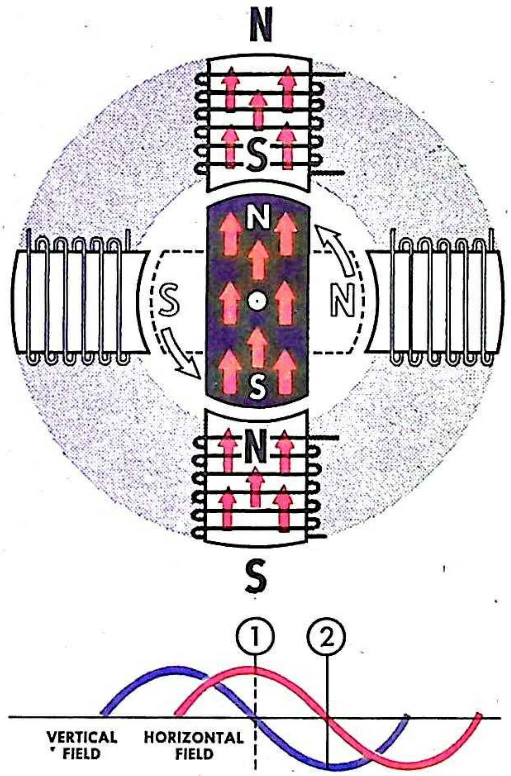


Figure 120—Opposite Rotation Produced When Phase Relationship of Fields Is Reversed

ing in a direction opposite to that shown in figure 117, and the polarity will be reversed. As in the preceding paragraph, magnetic attraction and repulsion will cause the rotor arm to move through a 90-degree arc in an attempt to align itself with the existing magnetic field (figure 119). This sequence of movement results in a complete revolution during every alternating current cycle. The rotor turns as it attempts to follow the rotating magnetic field. In this illustration, the rotation is in a clockwise direction.

(*b*) If the current flow in the vertical pair of electromagnets had been in the opposite direction at the beginning of the sequence, their polarity would have been reversed (compare figures 118 and 120), and the rotor bar would turn in the opposite direction. Therefore, it can be said that the direction of rotation of such a motor depends on the time relationship between the cycle of polarities of one pair of poles and the cycle of the other pair.

(2) WASTE-GATE-MOTOR OPERATION.

(*a*) The waste-gate motor has two sets of magnetic poles, but each set is made up of four poles instead of two as in the previous illustrations. The round armature or rotor is made up of many laminated segments similar to the single iron bar.

(*b*) One set of electromagnets is connected to the airplane's 400-cycle inverter through a condenser and forms the fixed-phase winding. (This winding corresponds to the horizontal field in the preceding examples.) The electrical action of the condenser is such that it causes the voltage across the fixed-phase winding to be approximately 1/4 cycle out of phase with the line voltage. The current through this winding is, however, in phase with the line voltage.

(*c*) The other set of electromagnets is connected to the amplifier and forms the amplifier-phase winding. This corresponds to the vertical field in the previous description. The voltage across the amplifier-phase winding is either in phase with the line voltage or 1/2 cycle out of phase. This means that the current through the amplifier-phase winding will either lead or lag the fixed-phase current by 1/4 cycle. Therefore, the phase of the power supplied by the amplifier controls the direction of rotation of the motor. When no power is delivered by the amplifier, the rotor remains stationary, as is the case in figure 117, when only two poles are used.

(*d*) For an explanation of how the signals sent to the amplifier vary the power output to the motor, refer to section IV, paragraph 1 *d* (2).

f. FUNCTION OF UNITS IN RELATION TO ENGINE OPERATION.

(1) GENERAL.—Modern aircraft engines are well designed and will give exceptionally good service if they are handled properly. The correct combinations of engine speed, manifold pressure, fuel-air ratio, carburetor air temperature, and cylinder-head temperature are all extremely important. It is therefore necessary to have an understanding of these factors as well as a knowledge of supercharger operation before it is possible to fully understand the operation of the type B electronic control system for turbosuperchargers.

(2) FUNDAMENTALS OF THE INTERNAL COMBUSTION ENGINE.

(*a*) MANIFOLD PRESSURE–HORSEPOWER RELATIONSHIP.—The internal combustion engine converts into mechanical power the energy produced by combustion of fuel. The liquid fuel is atomized or vaporized as it is mixed with air. This mixture is passed into the engine cylinders, compressed, and ignited. The heat of combustion and the resultant expansion of the gases produces the power which runs the engine. Thus the amount of mechanical power developed by a particular engine is dependent upon the amount, by weight, of fuel and air burned in the engine. The weight of fuel mixture which can be burned in the engine is, in turn, dependent upon the pressure of the gaseous mixture at the intake manifold. Therefore, within the limits imposed by the strength of materials in the engine, the horsepower output can be increased by increasing manifold pressure. Any means by which manifold pressure is artificially increased is known as supercharging.

(*b*) AIR CONSUMPTION IN AIRCRAFT ENGINES.—Aircraft engines require from 11 to 16 pounds of air for every pound of gasoline burned. The ratio of 15:1 and 16:1 are for highest efficiency, but maximum power is obtained with ratios of 12:1 to 14:1.

When the mixture control is set for a full-rich mixture, the engine uses approximately 0.55 pound of fuel per horsepower per hour. Thus, a 1200-horsepower engine uses approximately 660 pounds of gasoline an hour when operating at maximum power output. With an air-fuel ratio of 12:1, this would require 7,920 pounds of air per hour, or 99,000 cubic feet at sea-level density.

(3) THE INTERNAL ENGINE BLOWER.

(*a*) In order to pack 8,000 or 9,000 pounds of fuel mixture per hour into the cylinders of a 1200-

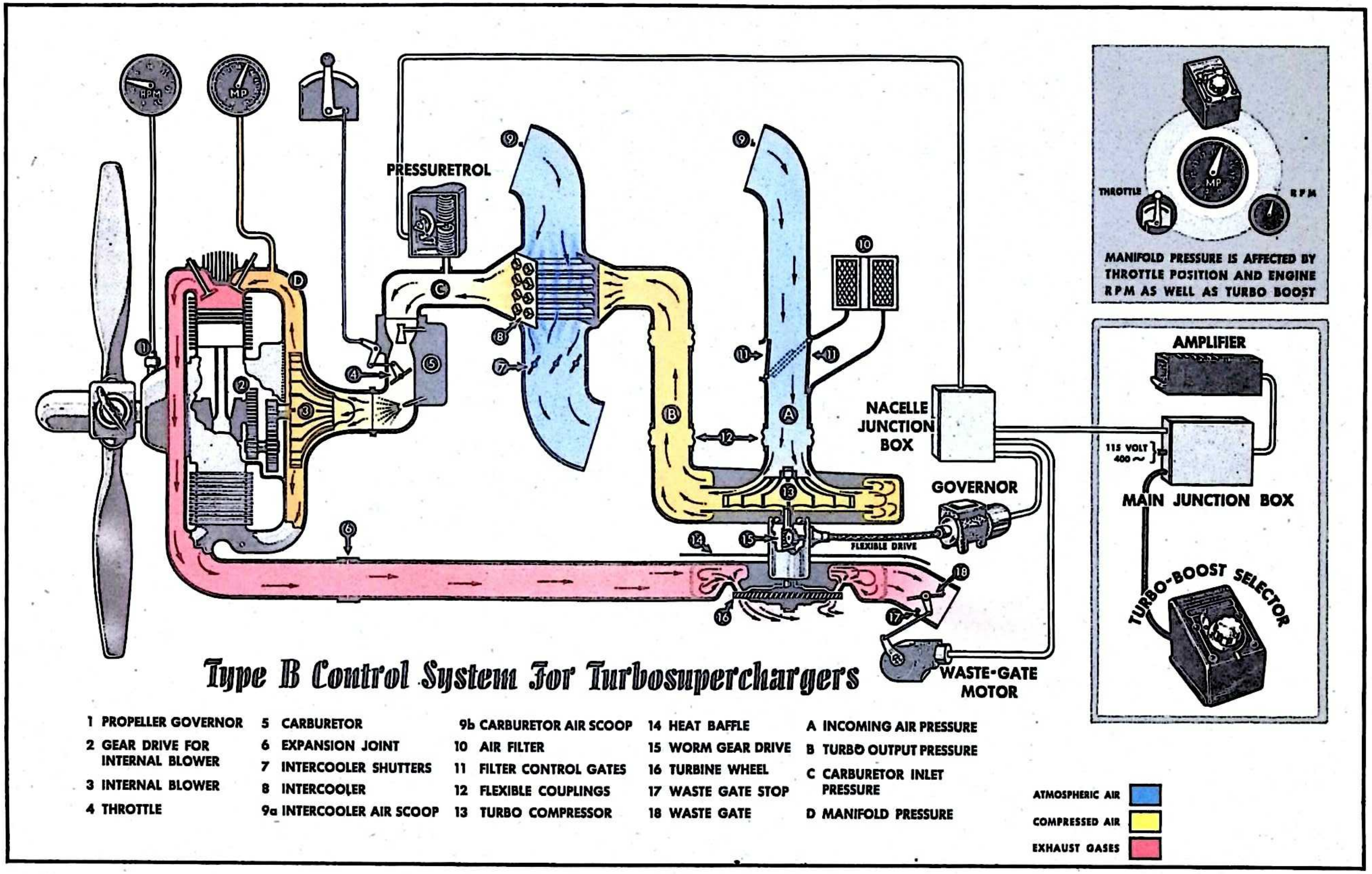


Figure 121—Schematic Drawing of Induction and Exhaust System of an Engine Equipped With Type B Control System for Turbosuperchargers

horsepower engine, it is necessary to maintain manifold pressure between 46 and 51 inches Hg.

(*b*) To obtain this manifold pressure, most aircraft engines are equipped with a rotary air-compressor or internal blower. (See No. 3, figure 121.)

(*c*) The internal engine blower is located between the carburetor and the intake manifold and is geared directly to the engine crankshaft. (See No. 2, figure 121.) Gear ratios on different installations vary from 6:1 to 10:1. The performance of an internal engine blower is limited by impeller-tip speeds and the heating of the mixture due to compression. The lower ratios are used on engines which are equipped with turbosuperchargers.

(*d*) The internal blower of a Wright engine in a B-17, when operating at 2500 rpm, is capable of increasing the induction-system pressure from approximately 28 inches Hg at carburetor intake to 46 inches at intake manifold (from C to D in figure 121). The blower of a Pratt & Whitney engine in a B-24 operating at 2700 rpm will increase the induction-system pressure from approximately 27 inches to 48 inches Hg.

(*e*) Inasmuch as the engine's internal blower is geared directly to the engine crankshaft, the amount of pressure boost that it will give varies approximately as the square of the engine rpm, provided the pressure at the blower inlet remains constant. For example, in a B-17, if the internal blower would boost the induction-system pressure from 28 inches Hg at carburetor intake to 46 inches at the intake manifold when the engine is running at 2500 rpm, it would only boost it to approximately 43 inches when engine rpm is lowered to 2300 rpm, provided the pressure at the blower intake remains the same.

(*f*) It is apparent that the manifold pressures obtainable with an internal engine blower of this type depend on two factors: the speed at which the blower is driven by the engine (determined by the gear ratio of the blower) and the carburetor inlet pressure (always slightly less than atmospheric pressure unless special equipment is provided for increasing carburetor inlet pressure).

(4) EFFECT OF ALTITUDE ON ENGINE PERFORMANCE.

(*a*) As shown in the following table, the atmospheric pressure is maximum at sea level and diminishes progressively at higher altitudes.

ALTITUDE ft.	PRESSURE in. Hg	PRESSURE lb/sq in.	TEMPERATURE °C	TEMPERATURE °F
0	29.92	14.70	+15.0	+59.0
5,000	24.89	12.23	+ 5.1	+41.2
10,000	20.58	10.11	− 4.8	+23.4
15,000	16.88	8.29	−14.7	+ 5.5
20,000	13.75	6.76	−24.6	−12.3
25,000	11.10	5.45	−34.5	−30.1
30,000	8.88	4.36	−44.4	−47.9
35,332	6.93	3.40	−55.0	−67.0
40,000	5.54	2.72	−55.0	−67.0
60,000	2.13	1.05	−55.0	−67.0

(From N.A.C.A. Report No. 538.)

(*b*) From the above table, it can be seen that atmospheric pressure decreases rapidly with altitude, and since the pressure boost derived from an internal blower depends on the carburetor inlet pressure as well as rpm, the manifold pressure produced at 20,000 feet will be correspondingly less than manifold pressure produced at sea level, with the same rpm. To compensate for this deficiency of the internal blower at high altitudes, some blowers are equipped with multiple- or variable-speed drive mechanisms. Thus the pressure boost obtained with the blower can be increased to offset the effect of decreasing atmospheric pressure.

(5) THE TURBOSUPERCHARGER.

(*a*) PRINCIPLES OF TURBO-SUPERCHARGER OPERATION.

1. Another method by which maximum manifold pressure can be obtained at high altitudes is by compressing the incoming air *before it reaches the carburetor.* This is the purpose of the turbosupercharger employed by many types of military aircraft.

2. Since the turbosupercharger is driven by energy obtained from exhaust gases, its speed may be regulated over a wide range and is not dependent on the speed of the engine, as in the case of the gear-driven internal blower.

3. The colorplate (figure 121) is a schematic drawing of the air intake and exhaust system of an engine equipped with a turbosupercharger, together with the units of the type B control system for turbosuperchargers. The names of these parts are shown in the nomenclature. The blue portions represent air at or near atmospheric pressure, the yellow portions represent air at various degrees of compression, and the red portion represents the engine exhaust gases.

4. The hot exhaust gases from the engine pass through the exhaust stack and enter the nozzle box

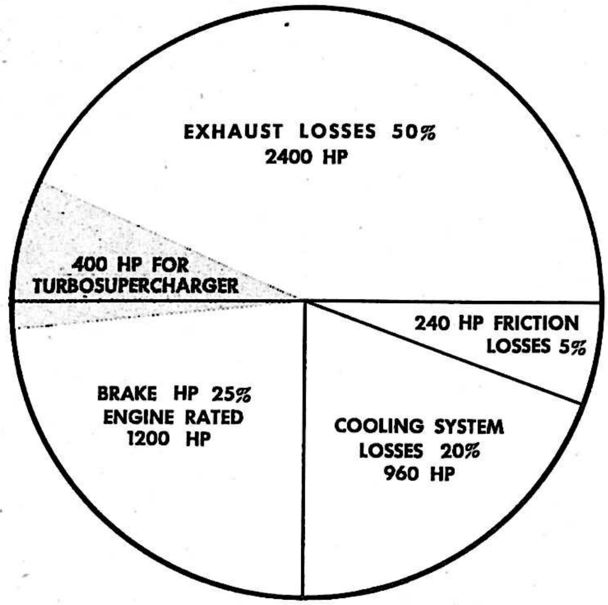


Figure 122—Power Input to a 1200-Horsepower Engine

which surrounds the entire periphery of the turbine wheel (16). When the waste gate (18) is moved to the closed position, the exhaust gases must pass through the turbine nozzles, which are rigidly fixed to the nozzle box so the gases will be deflected at an angle to the turbine buckets on the periphery of the wheel, causing it to rotate at high speed.

5. The speed of the turbine wheel and the direct-connected compressor impeller (13) can be precisely controlled merely by opening or closing the exhaust waste gate (18). When the waste gate is moved toward the closed position, pressure immediately builds up in the turbine nozzle box and the gases therefore impinge on the turbine wheel buckets at greater velocities, causing the speed of the wheel to increase rapidly. After the exhaust gas impinges on the turbine buckets, it escapes to the atmosphere.

6. As the waste gate is moved toward the open position, a greater percentage of the exhaust gas is bypassed directly to the atmosphere, causing a drop in pressure in the nozzle box and an attendant slowing down of the turbine wheel.

7. The operation of the centrifugal compressor is relatively simple. The air from the duct (9b) enters the compressor case near the center of the impeller (13), and is thrown radially outward and is therefore compressed by centrifugal action. The compressed air is then directed through the diffusing section toward the air discharge.

8. Though the power requirements of superchargers are quite high (360 horsepower required under certain conditions on some installations), this method of harnessing the power in exhaust gases which would ordinarily be dumped overboard furnishes the necessary power requirements with only a slight loss of usable power from the engine.

9. For example, when exhaust conditions are such that the back pressure penalizes the engine by 80 horsepower, it is possible for the turbine wheel to transmit approximately 400 horsepower to the compressor impeller, providing the net gain of 320 horsepower over what could have been attained if a direct-connected internal blower had been used to attain the necessary boost. (See figure 122.)

(*b*) THE TURBOSUPERCHARGER CONTROL SYSTEM.

1. The individual units of the type B electronic control system for turbosuperchargers, shown in figure 121, are fully described in section II preceding.

2. The electrical operation of the system in controlling the speed of the turbosupercharger is explained in section IV, paragraphs 1*a* through 1*e.*

(*c*) TYPICAL PRESSURE RELATIONSHIPS IN A TURBO-SUPERCHARGED ENGINE.

1. For purposes of explaining the pressure relationships of the turbosupercharger system, the following data are taken from an actual flight condition of an airplane flying at an altitude of 30,040 feet with the turbo-boost selector set at 6.9, throttles full open, and engine rpm 2330.

2. The atmospheric pressure at 30,040 feet is 8.9 inches Hg, and the temperature is −50° F. The indicated air speed of the airplane is 159 mph, and the air pressure at the entrance to the air scoop (9b, figure 121) is 9.9 inches Hg, which is slightly higher than atmospheric because of the "ram" caused by the speed of the airplane. Since the air loses a little pressure in the intake duct, the pressure at point (A) is 9.6 inches Hg and the temperature is −50° F. At this altitude the waste gate (18) is 39.5 degrees from the closed position and the turbine speed is 21,200 rpm. The air leaves the compressor (13) at a temperature of 157° F. and a pressure of 26.0 inches Hg (a pressure boost of 16.4 inches).

3. The air from the compressor then passes through the intercooler (8). The intercooler lowers the temperature to 42° F and the pressure to 25.7 inches Hg. The temperature and pressure at the car-

buretor inlet (C) is approximately the same as it is immediately after leaving the intercooler.

4. Since the throttles (4) are in the full-open position, the pressure drop through the carburetor is small, and it can be assumed that the pressure at the entrance to the internal blower (3) is still 25.7 inches Hg. However, considerable cooling takes place in the carburetor as a result of the evaporation of gasoline that is sprayed into the air stream.

5. The propeller governor (1) is set to hold the engine rpm at approximately 2330, and in this particular type of engine, the blower gear ratio (2) is 7:1; therefore the internal blower is running at a speed of 16,310 rpm. The air leaves the internal blower at a pressure of 38.6 inches Hg (pressure boost, 12.9 inches), as registered by the manifold pressure gage.

6. With the waste gate (18) 39.5 degrees from closed, the exhaust gas enters the turbine nozzle box at a pressure of 24.0 inches Hg and a temperature of 1560° F. The pressure differential across the turbine wheel is only 15.1 inches Hg (24 minus 8.9). The main source of power energy derived from the exhaust

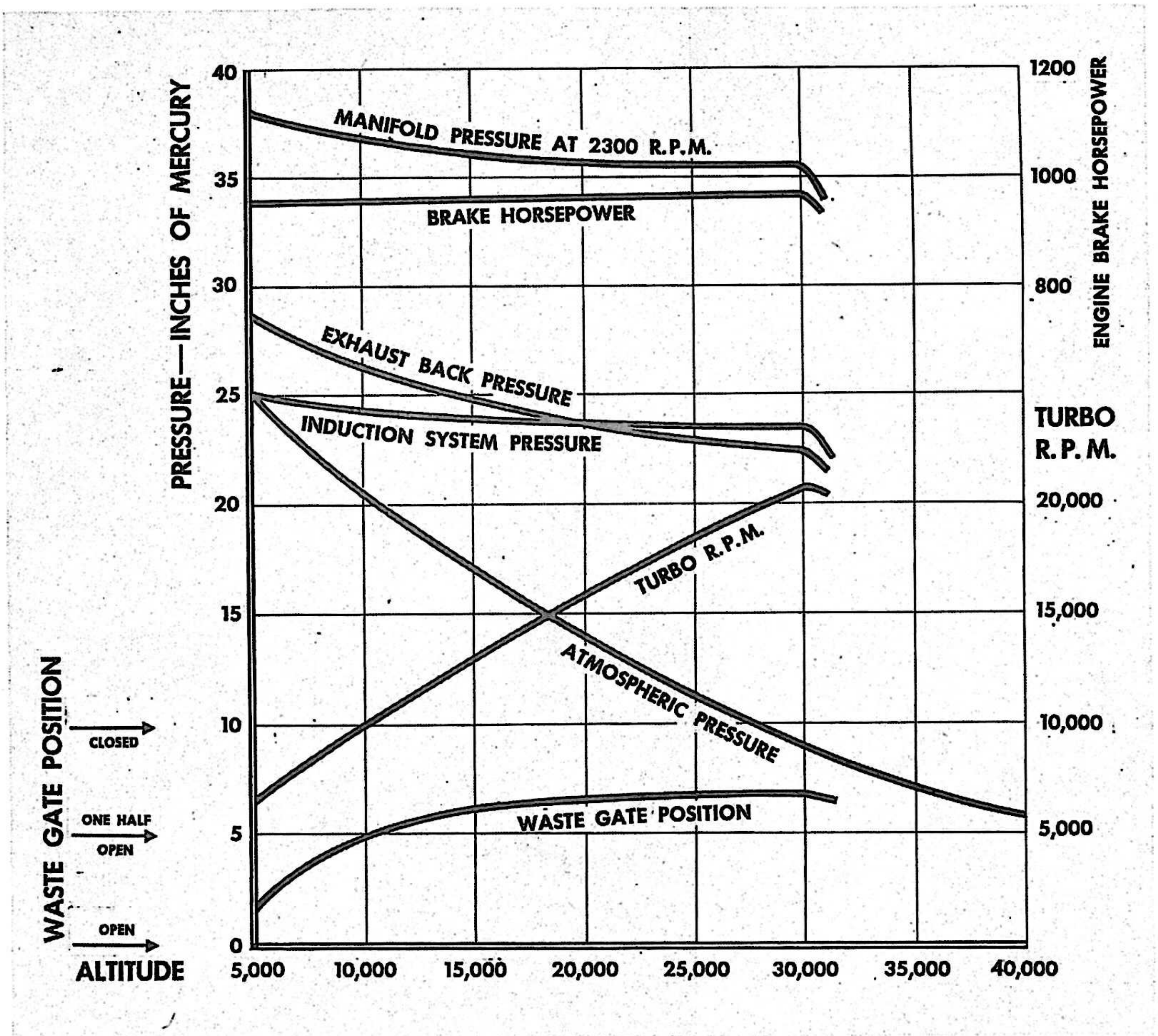


Figure 123—Typical Flight Curves for a Turbosupercharged Engine

gas is the high heat content of the gas. The turbine and nozzles are so designed as to convert a large portion of this heat energy into velocity, creating an impact on the buckets in the wheel.

7. The values given in the preceding paragraphs are reasonably accurate only for a particular set of conditions. If any of the conditions change, such as altitude or rpm, some of the values given will also change, but the control system will automatically readjust the speed of the turbosupercharger to restore a carburetor inlet pressure of 25.7 inches Hg, as long as the dial setting of the turbo-boost selector remains unchanged.

8. Figure 123 is a graph of typical operating conditions for a turbosupercharged engine during a rated power climb in a B-17 airplane from an altitude of 5,000 feet to 31,000 feet.

9. First, the engine rpm's were adjusted to 2300. This speed was held constant throughout the climb by the automatic propeller governors. The throttles were set at full-open position and a manifold pressure of 38 inches was selected by means of the turbo-boost selector.

10. The pressure boost supplied by the internal blower is represented by the difference between the induction-system pressure and the manifold pressure. As the engine rpm is constant, the manifold pressure varies only with the induction-system pressure, and the actual *amount* of boost remains almost constant. This is in contrast with the boost derived from the turbosupercharger. The control system acts to hold the induction-system pressure relatively constant while atmospheric pressure falls off rapidly. In order to hold the induction-system pressure constant, the Pressuretrol causes the turbo boost to be gradually increased to compensate for the drop in atmospheric pressure.

11. There is a droop in induction-system pressure of approximately 1¼ inches, producing a corresponding droop in manifold pressure of 2½ inches during the total climb from 5,000 feet to 30,000 feet. This droop occurs as a result of the balancing action of the wipers in the bridge system. As the induction-system pressure falls off slightly, the Pressuretrol moves the waste gate a little farther toward the closed position, causing the turbo to increase its speed and increase the induction-system pressure. These actions are simultaneous. Consequently, when the induction-system pressure starts dropping, the balancing potentiometer wiper and Pressuretrol wiper both move almost simultaneously to a new position of electrical balance. It is impossible for the induction-system pressure to return all the way to its original value because this would return the waste gate to its original position also, and no increase in turbo boost would be obtained.

12. This droop is an inherent characteristic of the control system. It is desirable from a standpoint of maintaining the horsepower approximately constant during the climb; for, if there were no droop in manifold pressure, the horsepower would constantly increase with altitude, partly as a result of the decrease in exhaust back pressure. (See curve, figure 123.) Decreasing the exhaust back pressure increases the volumetric efficiency of the engine, and lowering the carburetor inlet temperature increases the weight of fuel-air mixture entering the engine at a given pressure, both of which result in increased power output.

13. A study of the curve representing waste-gate movement also reveals some interesting special characteristics. The rpm of the turbosupercharger is a function of the pressure differentials across the turbine and the compressor wheels. This pressure differential is controlled by positioning the waste gate. From the curve, it is evident that at first a greater amount of waste-gate movement was necessary, but as the waste gate approached and passed the half-closed position, very little movement was required. This condition is a result of the flow characteristics of the waste gate, of the decrease in density of the air being handled by the compressor, and of the decrease in atmospheric pressure on the discharge side of the turbine. This waste-gate movement also affects the droop of the system. Because of a greater movement of the waste gate at the beginning of the climb, a greater droop also occurs at the beginning of the climb, and the amount of droop decreases as waste-gate movement decreases.

14. At an altitude of 30,000 feet the turbine has attained a speed of approximately 21,000 rpm. At this altitude the governor cuts in, as shown by the curve, producing a voltage signal which moves the waste gate toward the open position, thus preventing further increase in turbine rpm.

15. As the speed of the turbine can no longer increase, the induction-system pressure and manifold pressure both fall off rapidly as more altitude is gained. From this, it can readily be seen that for a given airplane, safe turbo speed is really the determining factor which limits the altitude at which the airplane may be flown *and still obtain the full rated horsepower* of its engines. Although the airplane can actually fly to

higher altitudes, it will eventually reach a ceiling above which it cannot rise, because the engine horsepower output drops off rapidly after the ceiling for the turbine has been reached.

2. OPERATION INSTRUCTIONS.

a. SYSTEM ENERGIZED BY INVERTERS.—The turbosupercharger control system is wired directly to the airplane's 400-cycle inverters and is therefore automatically energized when either inverter is running. After turning on the d-c power supply and the inverter switch, allow approximately two minutes for the amplifiers to warm up. The control system will then respond to the setting of the turbo-boost selector. When the dial is at "0," the turbos will be "off"; and when the dial is turned clockwise, turbo boost will increase as the turbos speed up. At low altitudes, however, no pressure boost can be expected until a dial position of "5" or higher is reached.

CAUTION

NEVER TURN INVERTER OFF WHILE ENGINES ARE RUNNING.

b. ENGINE RUN-UP TEST (*CREW CHIEF*).

(1) BEFORE STARTING ENGINES.—Set dial of turbo-boost selector at "0."

(2) INVERTER OUTPUT VOLTAGE.—Check a-c power-supply voltage with engines running. For satisfactory operation of the turbo control system, voltage should be 115 volts at input terminal in main "J" box, tolerance of 100 volts minimum, 125 volts maximum. If voltage does not fall within these limits, the trouble should be remedied before further checks are made. Since a slight change in d-c voltage will cause considerable change in a-c output, the generators must be ON and the d-c voltage must be carefully regulated so that the inverter output will be correct.

(3) ENGINE OPERATION.

(*a*) With dial of turbo-boost selector set at "0" and rpm control at maximum rpm position, check each engine separately at full throttle, noting any hunt in manifold pressure or rpm. Also be sure that manifold pressure reaches normal value for full-throttle operation without turbo boost.

NOTE

At full throttle and full rpm with turbos off, the manifold pressure will depend on the altitude of the air base; therefore, the crew chief should run a few checks on engines known to be functioning properly so that he will know what manifold pressures to expect for a given type of airplane at the altitude of the air base at which he is stationed.

(*b*) During the engine run-up test, if the dial of turbo-boost selector is set at "0" the turbo control system does not affect manifold pressure. Because of the flow of air through the compressors and the small amount of exhaust gas which escapes through the turbine wheels, the turbos will spin slowly while the engines are running, even though the waste gates are wide open. However, the turbos are considered "off," since little or no boost is derived from this rotation. *With waste gates open, the turbo control system has no effect on engine operation.*

(*c*) If faulty operation of any engine is indicated by this initial run-up, inspect the waste gates to be sure they are all open. If waste gates are open, the fault is clearly not in the turbosupercharger or its control system. To determine the cause of a malfunction that still exists with turbos off, check propeller governors, spark plugs, ignition harness, magnetos, filter dampers, carburetor, mixture controls, and throttle-stop positions. Differences in throttle-stop settings are a common cause of discrepancies in manifold pressure during engine run-up. It must also be remembered that sometimes an engine malfunction, such as faulty spark plugs, may show up only with the high manifold pressures produced by turbo boost, leading to the false assumption that the malfunction lies in the turbo control system rather than in the engine. Leaking intake and exhaust ducts, faulty valves, badly worn pistons, stuck rings, cracked cylinder heads, or cracked blocks also have an adverse effect on manifold pressure and rpm.

(4) TAKE-OFF MANIFOLD PRESSURE.

(*a*) If engine operates normally without turbo boost, open throttle and turn dial of turbo-boost selector to take-off position.

Take-Off Dial Settings*

AIRPLANE	B-17	B-24	B-29
100-octane gasoline	8	8	8
91-octane gasoline	7	6	—

*Refer to T.O. No. 02-1-38 for rpm and manifold pressures to be used with alternate grade fuels.

(*b*) Manifold pressure should increase to within 1 inch of take-off pressure after allowance is made

for difference between the rpm obtained and full take-off rpm.

NOTE

Because of slight variations in rpm at full throttle, there will be variations in manifold pressure on ground run-up. Manifold pressure should be approximately 1½ inches lower for each hundred rpm below maximum. If the engine fails to come within 100 rpm of take-off rpm, locate and remedy the cause of this engine malfunction.

(*c*) During routine engine run-up checks, if manifold pressure does not increase to within 1 inch of take-off pressure at the proper dial setting with full throttle and required rpm, refer to trouble-shooting procedure (section V, paragraph 5 *a*) for proper method of locating the malfunction in the turbo control system.

(*d*) Do not use the calibrators to compensate for low manifold pressure caused by a malfunction in either the engine or its accessories, as this practice will only lead to more serious difficulties.

(5) ACCELEROMETER OPERATION. (Omit this check when engine is operated on 91-octane gasoline.)—With dial of turbo-boost selector set at "8" and rpm control set at maximum, advance throttles rapidly from half-closed position on one engine at a time. Manifold pressure should not overshoot more than 2 inches either in ground run-up or in flight.

c. PILOT'S OPERATING INSTRUCTIONS.

(1) BEFORE STARTING ENGINES.—Set dial of turbo-boost selector at "0."

(2) SYSTEM ENERGIZED BY INVERTERS.—After turning on the d-c power supply and the inverter switch, allow approximately two minutes for the amplifiers to warm up. The turbo control system is then in operation.

CAUTION

NEVER TURN INVERTERS OFF WHILE ENGINES ARE RUNNING.

(3) TAXYING.—Set dial at "0" unless turbo boost is needed.

(4) BEFORE TAKE-OFF.

(*a*) Set propeller governors to take-off rpm.

(*b*) Turn carburetor air filters on.

(*c*) After checking magnetos, open throttle on one engine and check manifold pressure without turbo boost (dial at "0").

(*d*) If engine rpm and manifold pressure are O.K. without turbo boost, leave throttle open and turn dial to take-off position. (Refer to operating instructions, paragraph 2 *b* (4) (*a*) for take-off dial settings.) Manifold pressure should come up to within 1 inch of take-off pressure after making an additional allowance of 1½ inches per 100 rpm for difference between the rpm obtained and full take-off rpm. Refer to T.O. No. 02-1-38 for rpm and manifold pressures to be used with alternate grade fuels.

(*e*) Return dial to "0," and then repeat above check for each engine.

(*f*) After checking last engine, leave dial set for take-off manifold pressure.

(5) TAKE-OFF.—With dial set for take-off pressures, open throttles.

CAUTION

BE SURE GENERATORS ARE ON DURING AND AFTER TAKE-OFF.

(6) CLIMBING.

(*a*) After take-off, turn dial counterclockwise until desired manifold pressure is reached. Decrease rpm to proper setting. Reset manifold pressure with dial of turbo-boost selector if necessary. To return to climb power from cruise setting, increase rpm, open throttles, and adjust for necessary amount of turbo boost by turning dial of turbo-boost selector.

(*b*) Since the manifold pressures are equalized in ground calibration (section III, paragraph 5), small differences in manifold pressure can be expected in flight; however, avoid unnecessary changes of calibrator settings, as it should not be necessary to change these settings after initial ground calibration has been made.

(7) CRUISING.—Use dial to select manifold pressure. When reducing manifold pressure, if it cannot be lowered sufficiently with turbo-boost selector, pull back on the throttles. Decrease rpm to desired value, and then if necessary reset the manifold pressure with throttles and dial.

NOTE

If atmospheric conditions are such that carburetor icing may occur, maintain at least 4

inches of turbo boost and adjust intercoolers to maintain proper carburetor air temperatures. If engine operation does not require this amount of boost, reduce manifold pressure 4 inches with the throttles and bring manifold pressure back up 4 inches by increasing dial setting.

(8) EMERGENCY POWER. (To be used only with 100-octane gasoline.)—Increase rpm to maximum. Press dial-stop release and turn dial clockwise toward "10."

(9) FORMATION FLYING.

(*a*) The throttles, the turbo-boost selector, or the throttles and the turbo-boost selector combined may be used in formation flying, depending on the tightness of the formation, the position of the plane in the formation, and the altitude.

(*b*) In all cases, the setting of the turbo-boost selector must be such that the manifold pressure will not exceed the recommended limit for the rpm being used, even with throttles full open.

(*c*) At altitudes in the turbo overspeed range, to avoid a possibility of unstable manifold pressures it is advisable to set the turbo-boost selector below the point where the overspeed control begins to "cut in" on any engine, and to use the throttles to vary the power.

(*d*) Below 6,000 feet, the throttles must be used, as the effective range of the turbo-boost selector is very limited at low altitudes.

(10) DESCENDING.—Use the dial to select manifold pressure until throttle range is reached. For further reduction, use throttles. Maintain some turbo boost. Intercoolers should be open unless icing conditions prevail.

(11) LANDING.—Set propeller governors for maximum cruise rpm. Set dial for maximum cruise manifold pressure. Maintain desired power by use of throttles.

(12) STOPPING ENGINES.—When stopping engines, turn dial of turbo-boost selector to "0" before turning inverter off.

IN EMERGENCIES, RETARD THROTTLES TO REDUCE MANIFOLD PRESSURES.

3. OPERATION PRECAUTIONS.

a. GENERAL.

(1) BE SURE GENERATORS ARE "ON" DURING TAKE-OFF.—If voltage is low, waste gates may stop in a partly closed position, and excessive manifold pressures may result.

(2) NEVER TURN INVERTER OFF WHEN ENGINES ARE RUNNING.—With the inverter off, the control system for the turbosuperchargers cannot function, and the waste gate remains stopped in whatever position it may be at the time the power was turned off. If the waste gate is stopped in a partly closed position any slight increase in rpm or air speed will increase exhaust pressure. The increase in exhaust pressure gives more power to the turbine, thereby increasing the induction-system pressure. Increased induction-system pressure produces a further increase in exhaust pressure; thus, a vicious cycle is started which very rapidly builds up excessive manifold pressure.

(3) DANGER OF A-C POWER FAILURE.

(*a*) If a fuse blows or the electrical power supply fails, the waste gate will remain in whatever position it happens to be at the time of failure. If the airplane is in the air at the time of power failure, this will insure sufficient power to continue flight, and to stay in formation; however, excessive manifold pressure may be built up. If the airplane is equipped with direct-reading manifold pressure gages, the pressure will be registered even though the electrical power is off. The pilot will then know what manifold pressure is being developed and can control it by pulling back on the throttles.

(*b*) On airplanes equipped with Autosyn instruments, when the a-c power fails, the manifold pressure gages also fail. The pilot will have to judge the engine's operation by observation of airspeed or rate of climb until a-c power is restored.

(*c*) Erratic action of the Autosyn instruments may indicate a loose connection in the a-c power supply.

(4) FOLLOW INSTRUCTIONS CAREFULLY WHEN OPERATING AN ENGINE AT HIGH MANIFOLD PRESSURES.—Excessively high manifold pressures will result in extreme stressing of pistons and cylinder heads. High manifold pressures also increase cylinder-head temperatures rapidly and may cause detonation and preignition, especially when 91-octane gasoline is used. *Never use emergency power range when airplane is using 91-octane gasoline.*

(5) CARBURETOR AIR FILTERS SHOULD BE "OPEN" DURING TAKE-OFF AND "CLOSED" ABOVE 15,000 FEET.—Refer to applicable technical orders for further instructions on use of filters.

(6) FOLLOW MANUFACTURER'S RECOMMENDATIONS AND TECHNICAL ORDERS ON ENGINE OPERATION.—Technical orders on use of intercoolers, carburetor air temperatures, cylinder-head temperatures, proper rpm in relation to manifold pressure, procedure for increasing and decreasing power output, changes in grade of gasoline used, etc. must be followed or serious damage to the engine will result.

b. TAKE-OFF.—Take-off power with attendant high manifold pressure and maximum engine rpm should not be utilized for more than one to five minutes, or until the plane has cleared all ground objects. This short length of time is necessarily imposed because of the insufficient flow of cooling air around the cylinders during periods of low forward speed of the plane. When exceptionally high atmospheric temperatures exist, lower than usual take-off manifold pressures must be used in order to prevent detonation and loss of power.

c. CRUISING AND CLIMBING.

(1) When greater power output is desired, the pilot should first increase the engine rpm and then build up the manifold pressure so that the propeller will be able to utilize the increased power.

(2) It is very harmful to the engine to maintain a high manifold pressure with low rpm because the pistons will not be moving fast enough to efficiently absorb the energy from the expanding gases in the cylinder, and the high-frequency pressure waves generated under this condition will greatly stress the cylinder walls and combustion chamber.

(3) When less power is desired, the manifold pressure should first be decreased, and then the engine rpm's may be adjusted to a lower value. The reasons for this procedure are as explained above.

(4) Each aircraft engine manufacturer usually supplies curves or tables which serve as a guide as to where manifold pressures and engine speeds should be set to operate most efficiently under various conditions of service.

(5) In high-altitude flying, when a condition is reached where further turning up of the selector dial does not produce an increase in manifold pressure, the overspeed portion of the turbo governor is functioning to limit the speed of the turbo to safe values. When this condition is reached, the dial of the turbo-boost selector may be turned counterclockwise to the point where it can again control manifold pressure.

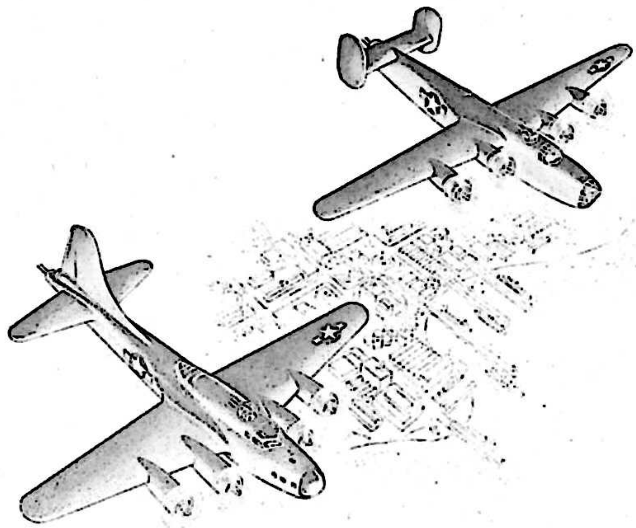
d. EMERGENCY POWER OR "WAR POWER."—Full emergency power, or "war power," which is obtained (at maximum engine rpm and full throttle) by releasing the dial stop and turning the dial of the turbo-boost selector to a setting of "10." causes excessive engine stress and should not be maintained for periods of more than two minutes.

Never use emergency-power range when operating engines on 91-octane gasoline.

e. DESCENT.—When descending from high altitudes, it is necessary to observe the engine temperature indicators when lower manifold pressures are utilized. It is always necessary to use manifold pressures great enough to insure that the engine will operate warm. This procedure is necessary so that the engines will be in the best operating condition when approaching the field for a landing.

Section V

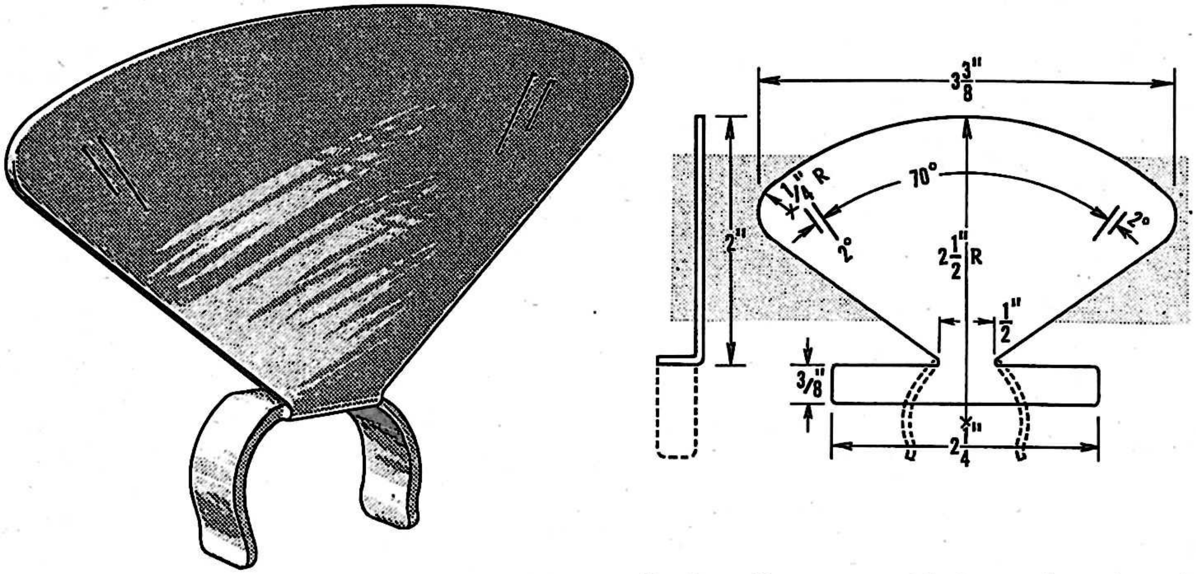
SERVICE INSPECTION, MAINTENANCE, AND LUBRICATION



1. SERVICE TOOLS REQUIRED.

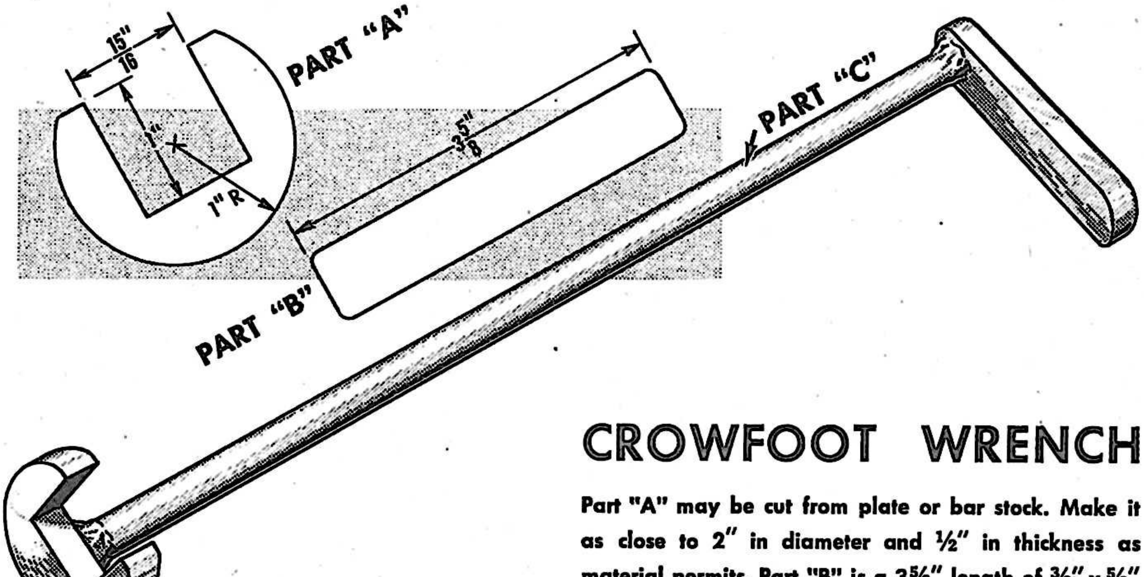
First Echelon maintenance of the type B control system for turbosuperchargers requires only two special tools—a crowfoot wrench and a protractor—which are used in installation of units. (See figure 124.) Standard tools and materials, readily obtainable at any service depot, are sufficient for all normal maintenance work. These are listed below. Mechanics familiar with the use of these tools will be able to carry out all maintenance procedure as described in this section.

Tool	Use
Screwdriver, 1/8 x 1 1/2"	General
Screwdriver, 3/16" stubby	General
Screwdriver, 3"	General
Screwdriver, No. 2 Phillips	General
Pliers, slip-joint	General
Pliers, long-nosed	General
Cutters, diagonal	General
Hand drill	General
Set drills, sizes 1 to 60, wire gage	General
Set taps, sizes 2-56 to 14-20	General
Tweezers	General
Flashlight	General
Jackknife	General
Rule, 6" steel	General
Tape, rubber	General
Tape, friction	General
Wrench, 8" Crescent	General
Wrench, 5/16" Spintite	General
Wrench, ratchet socket	General
Wrench, socket extension	General
Wrench, 3/8" socket	General
Wrench, 7/16" socket	General
Wrench, 5/16 x 3/8", open-end	General
Wrench, 7/16 x 3/8", open-end	General
Wrench, 9/16 x 11/16", open-end	General
Wrench, 15/16 x 7/8", open-end	Flexible drive coupling nut
Wrench, 15/16", crowfoot	Flexible drive coupling nut
Wrench, 3/32" Allen-head	Tightening setscrew in turbo-boost-selector knob
Volt ohmmeter	Circuit testing



WASTE-GATE PROTRACTOR

Cut from 16-gage material. First make right-angle bend. Then form curves by bending strip over piece of ½" pipe. Scribe angle lines as shown in sketch.



CROWFOOT WRENCH

Part "A" may be cut from plate or bar stock. Make it as close to 2" in diameter and ½" in thickness as material permits. Part "B" is a 3⅝" length of ⅜" x ⅝" bar stock. Part "C" is a 12" length of ⅜" rod. Weld together as sketched and then harden.

Figure 124—Special Service Tools Required for Field Maintenance of the Type B Control System for Turbosuperchargers

Inspection mirror	Inspection of inaccessible units and connections
Lubricant, AN-G-3a	Lubricating flexible drive shaft
Oil, AN-O-4	Oil for waste-gate motor
Sealing compound, U.S. Army Spec. 2-85-B	Sealing Pressuretrol connection
Safety wire	Safety-wiring screws
Cloths, white lint-free	Cleaning
Protractor	Adjusting waste-gate linkage

2. SERVICE INSPECTIONS.

The following column numbers refer to the columns listed in the Maintenance Inspection Record, AAF Form No. 41-B.

COLUMN NO. 10
PREFLIGHT INSPECTION

(To be performed prior to the first flight of the day.)

EXHAUST WASTE GATES.—Inspect waste gates for evidence of warping or bending. Refer to figure 125 for normal shape of waste gate.

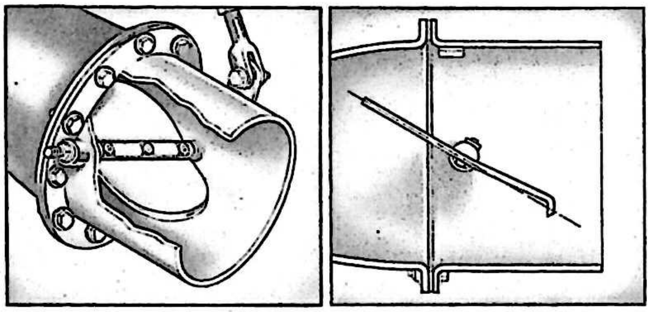


Figure 125—Normal Shape of Waste Gate

CAUTION

Do not attempt to open or close the waste gate while the linkage is connected to the waste-gate motor. Because of the brake in the motor, application of force will only place unnecessary strain on the linkage and the gear train in the motor.

With engines off, connect external power source. Turn inverter on and turn turbo-boost selector to "10." Then inspect all waste gates for uniformity of positions. If any gate is closed more than the other gates, it indicates that the calibrator setting on that engine has been changed to compensate for power plant defects. When this condition exists, carefully inspect the engine and engine accessories, performing the engine run-up test (section IV, paragraph 2 *b*) if necessary. Pay special attention to the possibility of induction-system and exhaust-stack leaks, as a very small leak would have great effect on turbosupercharger operation at high altitudes.

After locating and correcting the defects in the engine or its accessories, recalibrate the turbo control for that engine, as outlined in the ground calibration procedure, section III, paragraph 5.

AMPLIFIERS.—See that the amplifier cases in the turbo control system are not covered by parachutes, clothing, etc., preventing proper ventilation.

TURBO-BOOST SELECTOR.—Turn dial clockwise to stop. When stop is reached, arrow should point to "8." Press dial-stop latch and turn dial to "10." The dial-stop latch should work freely. Turn dial counterclockwise to a point below "8," and check to see that dial stop re-engages. Return dial to "0" (turbos-off position) before starting the engine.

INDUCTION SYSTEM AND EXHAUST STACKS.—When the airplane is flying combat missions, inspect the induction system and exhaust stacks for bullet holes before each flight.

COLUMN NO. 19
DAILY INSPECTION

(To be performed at any time during each day.)

WASTE-GATE LINKAGE.—Jiggle linkage to make sure there is no binding in linkage bearings. Also inspect linkage rod for shiny spots or wear, which would indicate it had been scraping against the fairing or other airplane structures.

FILTERS.—In very dusty or sandy areas, check cleanliness of carburetor air filters daily.

COLUMN NO. 27
MANIFOLDS AND SUPERCHARGERS

25-Hour Inspection

EXHAUST STACK.—Inspect exhaust stack for loose expansion joints and other leaks.

EXHAUST WASTE GATES.—Check exhaust waste gate for warpage, bending, or binding. To make this check, disconnect linkage rod from waste-gate arm and move gate from fully open to fully closed position. If any binding or friction is noticed, straighten waste gate or replace it.

WASTE-GATE MOTOR.—Check AN connector to see that it is inserted properly and is tight.

CAUTION

Never disconnect AN connector of waste-gate motor when inverter is on; this is apt to damage the amplifier.

Make sure motor is mounted solidly and has not shifted its position.

GOVERNOR AND FLEXIBLE DRIVE.—Inspect AN connector on governor to make sure it is properly inserted and tight.

See that the nut on flexible-drive connection is not cross-threaded and that it is tight.

Check governor mounting to make sure that governor is held solidly in place and has not shifted its position.

OPERATION OF AMPLIFIER AND WASTE-GATE MOTOR.—Plug in external power supply. Carefully check voltage of external power supply. (Voltages higher than 28.5 volts dc may result in weakened or burned-out amplifier tubes.) Turn on inverter switch. Set dial of turbo-boost selector at "8." Remove AN connector on Pressuretrol and plug in the special test potentiometer in place of Pressuretrol. (See figure 126.) Turn knob on test potentiometer until waste gate is fully closed.

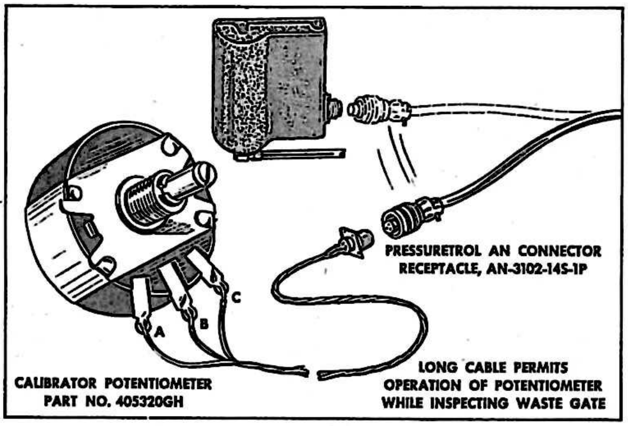


Figure 126—Service Test Potentiometer

NOTE

If the suggested test potentiometer is not available, the "jumper" method can be used without removing the AN connector of the Pressuretrol. Refer to section III, paragraph 2 *f* (2), for jumper method.

CLEARANCE OF LINKAGE ROD.—Check to see that there is at least ½-inch clearance between the linkage rod and any structural part of the airplane for all positions of the waste gate. Since the exhaust stack and turbine move backward an appreciable amount when heated, this much clearance is necessary to keep the linkage from binding.

CLEARANCE OF WASTE GATE FROM STOP.—With waste-gate motor in fully closed position, the waste gate should be approximately 3/32 inch away from stop inside exhaust pipe.

WASTE-GATE POSITIONS.—Remove test potentiometer used for closing waste gate, and replace Pressuretrol AN connector. If jumper method was used, remove jumper and replace "J" box cover. Turn dial of turbo-boost selector to "8" and look at exhaust waste gates. At sea level, or at altitudes slightly above sea level, the waste gates should be open or almost open when the engines are not running, even with the dial at "8"; but at bases of higher altitude, the waste gates will be partly closed when dial is turned to "8."

Because of the small guide key in the Pressuretrol AN-connector receptacle, great care should be used to insure that the plug is properly matched with the receptacle when it is inserted.

PRESSURETROL CONNECTIONS.—Inspect pipe or hose which connects Pressuretrol to induction-system duct. Check for leaks or cracks in hose and for loose clamps. A leak will result in erratic control and will introduce manifold-pressure "hunting" at certain powers or altitudes.

INDUCTION SYSTEM.—Check for leaks in rubber couplings in induction-system ducts. Also check gasket between duct and the turbosupercharger compressor housing.

Inspect turbo air-intake ducts for obstructions such as dirty filters.

Check for loose or worn linkage on filter control gates.

TURBO-BOOST SELECTOR.—Check AN connector to be sure it is properly inserted and tight.

Turn dial of turbo-boost selector to "10." Waste gates should go to half-closed position or beyond.

Turn dial to "0." Waste gates should open fully. If any gate does not move as it should, refer to trouble-shooting procedure (paragraph 5 *a* following) for methods of locating the cause of the malfunction.

Test operation of dial on turbo-boost selector to see that it turns freely but not loosely. It should be tight enough to prevent turning from vibration.

Make sure Allen-head setscrew in knob is tight.

CAUTION

If knob does not turn easily, do not try to force it. If shaft binds, replace complete unit.

INVERTERS.—Check AN connectors on airplane's inverters to see that they are properly inserted and are tight.

Check main fuse contacts and wire connections to fuse clips on 400-cycle supply. (Refer to section III, paragraph 3, for location of main fuse.) Also check inverter fuse connections if the airplane is equipped with separate fuses for each inverter.

Check output voltage of each inverter by connecting an a-c voltmeter to main "J" box terminals $\boxed{\text{B10}}$ and $\boxed{\text{B1}}$. Voltage should be 115 volts (plus 10 volts, minus 15 volts) when d-c voltage is 28 volts. This tolerance covers the voltage limits for proper turbo control system operation.

Since the entire turbo control system receives its power from the inverters, careful maintenance of the inverters is necessary for dependable operation of the turbo control system. Refer to T.O. No. 03-5H-5 on maintenance of Type MG149F inverters.

Disconnect external power supply.

MAIN "J" BOX.—Check inside box for loose terminal connections, especially terminal $\boxed{\text{B10}}$, where main power supply connects. To check terminals, grasp Sta-kon lugs as close to terminal as possible and jiggle sideways, using very slight pressure.

CAUTION

Do not pull on wires for this inspection, as this method would probably cause breakage rather than prevent it.

Visually inspect wires in main "J" box for evidence of breaking at Sta-kon lugs.

Remove loose or foreign material from inside box.

In very moist, humid climates, check for corrosion around leads and terminals inside "J" box.

Check ground lead from main "J" box where it anchors to airplane, to see that it is firmly attached.

AMPLIFIERS.—Remove amplifiers from their case and press down on tubes to make sure they are not loose in their sockets.

Blow out any dust that has accumulated around tube sockets.

Visually inspect fuse contacts and all soldered connections.

Replace amplifiers in their cases and reconnect AN connectors.

Be sure each connector is properly inserted and tight.

Make sure Dzus fastener locks amplifier in its case.

Inspect Lord mounts under amplifier platforms. If rubber is badly cracked, replace the mounts.

WIRING HARNESS.—The wiring harness is regularly inspected every 50 hours. In very moist, humid climates, however, it may be necessary to inspect the harness more frequently. When operating under these special climatic conditions, check the long cables inside the wing and inside the engine nacelles every 25 hours for corrosion and for accumulation of moisture inside the tape or Irvolite covering on cable. If wing and nacelle disconnects are used, they should be inspected for good contact.

FLEXIBLE SHAFTS.—In tropical areas or during very hot weather, disconnect the flexible drive from the governor every 25 hours, and inspect the flexible shaft for lubrication. If necessary, lubricate with light grease, Specification AN-G-3a. In normal operation, the inspection of the flexible shaft is taken care of at the 100-hour inspection.

50-Hour Inspection

In addition to performing the preflight, daily, and 25-hour inspections, make the following checks:

PRESSURETROL.—Carefully inspect Lord mounts. If rubber is badly cracked, replace mounts.

Remove cover plate and check potentiometer wiper to see that it is tight on its shaft. To do this, grasp wiper near clamp and twist counterclockwise until wiper reaches upper end of potentiometer winding. When released, wiper should return to its original position if it has not slipped. If wiper is loose, replace Pressuretrol.

Note position of wiper on potentiometer winding. At sea level, wiper should be about one-fourth of the distance up from the bottom of the potentiometer winding. If wiper is above the center of the potentiometer winding, the Pressuretrol may be out of calibration, or the reference bellows may be leaking.

NOTE

Where altitude of air base is above 5,000 feet, normal position of wiper will be slightly above center of potentiometer winding.

Inspect red lacquer on calibration screws to see that they have not been tampered with. Calibration of the Pressuretrol is Fourth Echelon work.

Inspect all soldered connections.

Carefully inspect base of AN-connector pins inside Pressuretrol for loose strands of wire.

Replace cover on Pressuretrol.

CAUTION

NEVER OIL ANY PART OF THIS UNIT.

NACELLE "J" BOX.—Check terminals for loose connections. To check terminals, grasp Sta-kon lugs as close to terminal as possible and jiggle sideways, using very slight pressure.

CAUTION

Do not pull on wires for this inspection, as this method would probably cause breakage rather than prevent it.

Inspect wires to see that they are not broken at Sta-kon lugs.

Check mounting of condenser and transformer.

Examine condensers for oil leakage. If there is evidence of leakage, replace the condensers.

Check to see that lock washers are on all terminals.

Remove any loose or foreign material from inside box.

Visually inspect soldered connections on the two 50,000-ohm resistors and on condensers.

Check Dzus fasteners to see that cover is held securely.

In very moist, humid climates, check transformers for deterioration of insulation and for corrosion around leads and terminals inside "J" boxes.

WIRING HARNESS.—Check wiring harness inside fuselage at all points where wear or abrasion might occur. Also check harness inside engine nacelle from nacelle "J" box to each unit.

100-Hour and Subsequent Inspections

The 100-hour and subsequent inspections are grouped together for convenience. For these inspections, *repeat the procedures outlined in the complete 50-hour inspection,* adding the following checks.

100-Hour Inspection

FLEXIBLE DRIVE.—Disconnect flexible drive at governor end, pull out the flexible shaft, and inspect shaft for wear. Lubricate if necessary (Grease Specification AN-G-3a). If flexible drive is worn at some point, replace the complete drive.

Replace flexible shaft. After sliding it into the housing, press it inward and turn until it slips into place, engaging the drive connection on the turbosupercharger.

Reconnect flexible drive to governor, being very careful not to cross-thread the nut.

GOVERNOR.—Disconnect AN connector from the turbo governor.

Remove the two screws which hold the cup-shaped cover on the accelerometer end of the governor. (See figure 127.) Remove the cover, being careful not to get dirt into the unit.

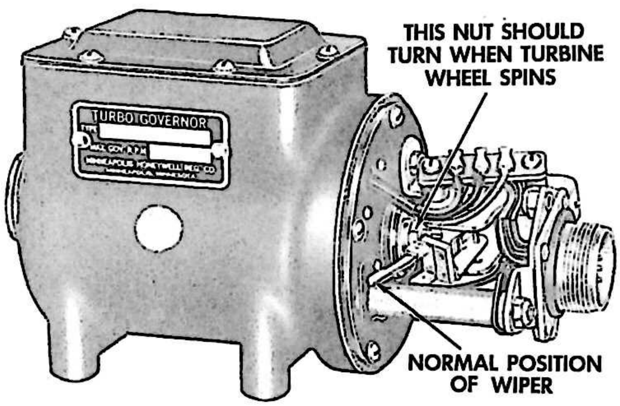


Figure 127—Governor With Accelerometer Cover Removed

While someone spins the turbine wheel, watch the nut directly above the bearing plate, inside the governor, to see that it turns with the turbine wheel. (There is a reduction gear ratio between the turbine speed and turbo-governor speed.)

CAUTION

Do not press on wipers of accelerometer potentiometer, as this may change their contact tension.

With the blade of a thin screwdriver, carefully slide wiper away from dead-spot end of potentiometer winding in accelerometer; then release the wiper, allowing it to return under the pull of its own spring. This check will insure that the wiper moves freely.

CAUTION

This unit is never oiled except in Fourth Echelon maintenance.

Visually inspect flexible lead and soldered connections.

NACELLE "J" BOX.—Check output voltages of transformer. To do this, connect an external power source to airplane, turn on inverter, and adjust d-c voltage input to give 115 volts inverter output.

Voltage from transformer secondaries should then be as follows:

Terminals	Voltage
B7 to B9 . . .	30 volts (+2.5, −1.5)
B5 to B3 . . .	24 volts (+2.5, −1.5)
B3 to A2 . . .	6 volts (+ .4, − .4)
A2 to B2 . . .	12 volts (+ .7, − .7)

TO CHECK ACCELEROMETER CONTROL.—The accelerometer control should be checked during the first flight following the 100-hour inspection. At some altitude above 6,000 feet, retard the throttles *individually* to half-closed position, and then advance throttles rapidly to full-open position. The manifold pressure should not overshoot more than 2 inches *unless rpm overshoots also.* If engine *rpm* overshoots, repeat this procedure several times until propeller governor holds engine speed relatively constant.

300-Hour Inspection

AMPLIFIER.—Replace the two 7C5 tubes in the amplifier after approximately 300 hours' operation.

TO CHECK OVERSPEED CONTROL.—Immediately following a complete installation of the type B control system for turbosuperchargers and at approximately 300-hour intervals thereafter, the airplane should be flown to an altitude of 35,000 feet. This altitude is sufficient for checking overspeed operation on B-17, B-24, and B-29 airplanes equipped with type B turbosuperchargers.

NOTE

If the carburetor intake duct is leaking, the overspeed will cut in at a much lower altitude. A serious leak in the exhaust stack may be misconstrued as overspeed control operation, as it will also cause a falling off in manifold pressure before an altitude of 35,000 feet is reached.

At 35,000 feet, level off and set propeller governors for maximum cruise rpm. Slowly turn dial of turbo-boost selector toward "8." At some point before "8" is reached, the manifold pressure should stop increasing on all engines, indicating that the overspeed controls are cutting in. If the manifold pressure continues to increase on one or more engines, keep turning the dial clockwise, but do not exceed the maximum cruise manifold pressure. At 35,000 feet altitude, if the governor is set for the proper turbine speed the overspeed control should operate before maximum cruise manifold pressure is reached. When checking one of the engines at full throttle, the throttles may be retarded on the other engines.

NOTE

The overspeed control on the inboard engines of a B-17 will usually cut in at approximately 2 to 4 inches lower manifold pressure than the pressure at which the outboard engine superchargers reach overspeed. This is caused by pressure losses in the longer exhaust ducts and carburetor intake ducts.

Recheck the overspeed by lowering dial setting into control range, and again slowly increase dial setting until manifold pressures cease to increase.

500-Hour Inspections

Every 500 hours, or at time of engine overhaul, replace the following turbo control units with new or rebuilt units:

- Waste-gate motors
- Governors
- Pressuretrols
- Amplifiers
- Turbo-boost selector
- Flexible drives

3. MAINTENANCE.

a. GENERAL.—Cleaning of potentiometers, replacement of parts inside units, calibration, and overhaul of units will be left to Fourth Echelon maintenance.

For location and installation of all turbo control system units, refer to section III of this handbook.

b. REMOVAL OF UNITS.

(1) TURBO-BOOST SELECTOR.

(*a*) B-17 AIRPLANES.—To remove the turbo-boost selector from the airplane, disconnect the AN connector. Next take out the screws holding the AN-connector receptacle and also the screws which hold

the case to the pedestal. The complete unit can then be lifted from the airplane.

(*b*) B-24 AIRPLANES.—The turbo-boost selector is mounted on the control pedestal between the pilot and copilot. (See figure 48.) To remove the unit, disconnect the AN connector and remove the four mounting screws.

(*c*) B-29 AIRPLANES.—The turbo-boost selector is mounted inside the control pedestal between the pilot and copilot. (See figure 49.) The dial, the knob, and the dial stop all extend above the pedestal, but the remainder of the unit is inside the pedestal. The AN connector is accessible by removing a small plate on the side of the pedestal.

The turbo-boost selector is attached to the pedestal cover with two screws. To remove the unit, disconnect the AN connector, turn the dial to zero, and then loosen the Allen-head screw in the knob. Remove the knob by turning it counterclockwise until it comes off the shaft. (On some later models the shaft will not be threaded; therefore, the knob will lift off.) Before removing the dial-stop plate, note toward which calibrator the notch points so that the plate can be replaced correctly. Remove the dial-stop plate and washers, laying them out in order so that they can be replaced properly.

To free the mechanism, unfasten the pedestal cover and raise it sufficiently to reach the unit. While the unit is held in place, remove the two mounting screws, one on each side of the knob.

(2) PRESSURETROL.

(*a*) B-17 AIRPLANES.—To remove the Pressuretrol, remove the AN connector and disconnect the pressure line. Next remove the bolts in the Lord mounts of the Pressuretrol bracket. (See figure 51.) This frees the Pressuretrol from the frame of the mounting bracket, which is left in the airplane.

(*b*) B-24 AIRPLANES.—Remove the Pressuretrol by removing the bolts through the Lord mounts in the same manner as described for a B-17.

(*c*) B-29 AIRPLANES.—Remove the Pressuretrol by removing the three screws which attach it to the plates of the mounting bracket. (See figure 53.)

(3) TURBO GOVERNOR.

CAUTION

On most installations, the governor mounting bracket is slotted, permitting adjustment to different types of turbo-oil-pump installations. Before the bracket is removed, its exact position should be marked in order to assure proper alignment of governor and flexible drive when the governor is remounted in the airplane.

(*a*) B-17 AIRPLANES.—For location of the governor on the inboard and outboard engines, see figures 56 and 57.

To remove the governor, detach the AN connector, disconnect the flexible drive, and then remove the four bolts holding the bracket to the airplane. The governor can then be separated from the bracket by removal of four 10-32 studs.

(*b*) B-24 AIRPLANES.—For location of the governor, see figure 58.

To remove the governor, detach the AN connector, disconnect the flexible drive, and unbolt the governor from the mounting bracket.

(*c*) B-29 AIRPLANES.—For location of governors on both inboard and outboard engines of a B-29, see figures 59 and 60.

On the outboard engines, the governor may be reached by removing the small access plate on the side of the nacelle (figure 59); on the inboard engines, however, the narrow sheet metal plate just below the turbo must be removed (figure 60).

In both cases, the governor is bolted to an aluminum bracket with four 10-32 hex-head bolts; however, the design of the two brackets differs considerably.

To remove the governor, the flexible drive and AN connector should be disconnected first. On the outboard engines, remove the bolts which hold the governor to its mounting bracket, leaving the bracket attached to the airplane. (See figure 59.) On the inboard engines, where the governor is less accessible, first remove the two outer governor mounting bolts. This frees the upper end of the bracket support. Remove this bracket support next. The two inner governor mounting holes can then be removed, leaving the remainder of the mounting bracket in place.

(4) FLEXIBLE DRIVE.—To remove the flexible shaft, disconnect the drive at the governor end and pull the shaft from its housing. This applies equally to B-17, B-24, and B-29 airplanes. If the shaft is badly

worn, disconnect the shaft housing from the turbosupercharger and replace the complete flexible drive. In a B-29, it will be necessary to remove part of the turbosupercharger before the connection to the flexible drive can be reached.

(5) AMPLIFIERS.—The amplifiers are mounted on individual platforms. To remove the complete amplifier, disconnect the AN connector and loosen the Dzus fastener which locks the amplifier case to its mounting platform. The same type of mounting is used on B-17, B-24, and B-29 airplanes.

(6) WASTE-GATE MOTOR.

CAUTION

Before removing the waste-gate motor, note the exact position of the motor crank arm relative to the waste-gate arm as a reference for checking the motor-arm position when reconnecting the linkage. Do *not* remove the motor crank arm while the motor is still mounted in the airplane. Also, carefully mark the exact position of the mounting bracket so it can be remounted in the same position. Any change of bracket position will require readjustment of the linkage.

(*a*) B-17 AIRPLANES.—For location of the waste-gate motor, see figures 71 and 72.

To remove the waste-gate motor from the airplane, detach the AN connector and disconnect the linkage from the waste-gate-motor arm, leaving the crank arm on the motor.

The nut to be removed on the linkage is a 10-32 castle nut secured with a cotter pin.

On factory installations, because of the inaccessibility of the bolts in the base of the waste-gate motor when mounted in the airplane, the motor should be removed complete with bracket, or with part of the bracket attached. Four bolts anchor the bracket, and the nuts for these bolts are welded or staked to the airplane.

(*b*) B-24 AIRPLANES.—For location of the waste-gate motor, see figure 80.

Since the screws holding the motor to the bracket are rather inaccessible when the motor is mounted on the airplane, it is best to remove the bracket with motor attached and then to remove the motor from the bracket, if desired. To remove the motor and bracket, disconnect the linkage from the motor arm, remove the AN connector, and unbolt the bracket from the turbosupercharger housing. In replacing the motor, note that the holes in the base of the motor are not all of the same depth. Be sure the short screw goes into the shallow hole.

(*c*) B-29 AIRPLANES.—To take out the motor, remove the sheet-metal cover directly above the turbosupercharger (figure 74). Reach up through the opening and disconnect the AN connector. Pull out the cotter key and remove castellated nut; then pull out the pin which connects the waste-gate linkage to the waste-gate-motor arm. The motor can then be removed from the bracket by cutting the safety wires and removing the four 1/4-inch mounting screws in the base of the motor, leaving the bracket in place in the airplane. (See figure 77.)

4. LUBRICATION.

With the exception of the flexible drive, no field lubrication is required on *any* type B control units for turbosuperchargers.

a. FLEXIBLE DRIVE.—The flexible shaft should be removed from its housing and lubricated with light grease, Specification AN-G-3a, after every 100 hours of operation, or more frequently when operating in tropical areas.

b. WASTE-GATE MOTOR.—The gear train of the waste-gate motor runs in oil, which is sealed into the unit at the factory; therefore, no field lubrication is required. If an appreciable leak should develop, remove the motor and send it to a Fourth Echelon repair station for complete overhaul. In an emergency, if another waste-gate motor is not available, the filler plug may be removed and the motor drained and refilled with one ounce of light oil, Specification AN-O-4. Replacement of the shaft seal cannot be done in First Echelon work.

NOTE

LUBRICATION OF ANY OF THE TURBO CONTROL UNITS WHILE THEY ARE MOUNTED IN THE AIRPLANE IS LIKELY TO RESULT IN FAULTY OPERATION.

CAUTION

DO NOT OIL BEARINGS OF THE WASTE-GATE LINKAGE; THE OIL IS LIKELY TO CARBONIZE AND CAUSE BINDING OF THE BEARINGS.

5. SERVICE TROUBLES AND REMEDIES.

a. TROUBLESHOOTING PROCEDURE.

(1) GENERAL.—This troubleshooting procedure outlines a careful and systematic method of locating the cause of a malfunction which appears to be in the turbo control system.

The first step is an engine run-up check which is used to separate engine malfunctions from turbo-control-system malfunctions. In many instances an engine malfunction, or a malfunction in some engine accessory other than the turbo control system, will affect manifold pressure equally as much as a malfunction in the turbo control system itself.

If the engine run-up check proves that the engine and its other accessories are O.K., the next step is to perform inspections to locate mechanical malfunctions in the turbo control system which cannot be found by electrical checks.

If the engine run-up check and inspections do not reveal the cause of the malfunction, make a detailed electrical check of the turbo control system to isolate the trouble to a definite unit or an area small enough that it can be visually detected.

To find and repair the cause of a malfunction in the shortest possible time, maintenance men should work in pairs.

NOTE

Be careful not to develop the habit of assuming that for a given symptom the same malfunction always exists. Always make a systematic test. Attempts to short-cut a systematic troubleshooting procedure frequently result in great losses of time.

Do not attempt to do internal wiring of the turbo control units or repairs within the units; this is Fourth Echelon work. If any unit proves defective, replace it with another; however, *do not replace a unit without first attempting to determine, by electrical checks, whether the unit is defective.*

(2) DEFINITIONS.—In this troubleshooting procedure, certain terms are used which need defining:

(*a*) A *malfunction* is an abnormal action in any part of the system resulting from shorts between wires, shorts-to-ground, opens, reversal of lead wires, power failure, or mechanical failures.

(*b*) A *short* is an electrical contact between parts of an electrical circuit at some point other than an established junction point. For example, if the insulation breaks down on or becomes worn off two wires which are in close proximity, the two electrical paths may become interconnected.

(*c*) An *open* is a break in the electrical circuit. If a wire breaks at any point or becomes disconnected from a terminal, or if a potentiometer wiper fails to make contact with the winding, an open results.

(*d*) In electrical systems, the metal framework to which the controls are anchored is frequently used to complete the circuit. Whenever a wire or terminal makes contact with the metal frame, the point of contact is known as a ground. If an unintentional ground occurs, such as might be produced by failure of the insulation on a wire, the ground is referred to as a *short-to-ground.*

(*e*) The term *reversal,* as it pertains to the type B turbo control system, refers to a transposition of connections in some part of the system resulting in wrong direction of waste-gate movement from part or all of the controls in the system.

(3) ENGINE RUN-UP TEST.—To isolate the cause of a malfunction affecting manifold pressure, the first step is to perform the regular engine run-up test as outlined in section IV, paragraph 2 *b.* This test is to determine, if possible, whether the cause of the malfunction is in the turbo control system, or whether the engine or related accessories are at fault.

(4) INSPECTION PROCEDURE.—If the engine run-up test indicates that the engine and its other accessories are O.K., perform the preflight, daily, and 25-hour inspections on the turbo control system, as outlined in section V, paragraph 2, plus additional inspections as follows:

(*a*) Inspect turbo governor and flexible drive as instructed in the 100-hour inspection procedure.

(*b*) Revolve turbine wheel by hand to check clearances, especially clearance between wheel and nozzles. Also check the wheel for missing buckets and for evidence of warping.

(*c*) Inspect carburetor intake ducts for bullet holes, for cracks in flexible coupling, and for loose or broken clamps on flexible couplings in the ducts.

(*d*) If these inspections and engine run-up test fail to reveal the cause of the malfunction, proceed to isolate the trouble electrically.

(5) LOCATING A MALFUNCTION BY ISOLATING IT ELECTRICALLY.

(*a*) FOUR-ENGINE WIRING DIAGRAM. (See figure 128.)—This wiring diagram of a four-engine installation shows all wire numbers, main "J" box

terminals, nacelle "J" box terminals, AN-connector terminals, color coding of wires, ground connections, resistances of potentiometers, transformer voltages, direction of potentiometer-wiper movement to open the waste gate, fuses, and other circuit details for the turbo control system as installed by Minneapolis-Honeywell. Installations made by aircraft factories will follow a similar circuit diagram, but interconnecting wires will be identified by different numbers.

Before beginning a troubleshooting check, maintenance men should study this diagram to be thoroughly familiar with all symbols, the path of the signal, and the division points between the main components of the system. All references to terminals and wires used in the following troubleshooting procedure pertain to the wiring diagram.

(*b*) EXPLANATION OF ISOLATION METHOD.—To isolate a malfunction, first divide the system into major components which perform a complete function, such as the entire bridge circuit or the complete amplifier, and then check each component, eliminating from further consideration those components which show no disorders. After isolating the trouble to a major component, subdivide the component and check each part. By this method of troubleshooting, the malfunction may finally be isolated to a very small part of the electrical circuit or to one unit of the system.

(6) DESCRIPTION OF CONTROL SYSTEM.

(*a*) MAJOR COMPONENTS.—The complete turbo control system can be divided into four major electrical components: the power supply, the amplifier, the bridge system, and the waste-gate-motor circuit. Each of these major components can then be further subdivided in the process of isolating the malfunction to a particular unit.

(*b*) SUBDIVISIONS.

1. POWER SUPPLY.—The entire control system for all engines is powered by one 400-cycle, 115-volt inverter.

A spare inverter wired into the circuit can be put into operation merely by throwing a switch.

The power is supplied through a 20-ampere fuse located in the inverter fuse box of a B-17, and a 5-ampere fuse in the inverter fuse box of a B-29. A 5-ampere fuse is used in the copilot's fuse box of a B-24. If the inverter fails or the main fuse blows, all four waste gates will remain in whatever position they happen to be at the time of power failure.

There is also a 1-ampere fuse which controls the power supply for each individual engine control system. This fuse is located inside the amplifier case. The division point between the power supply and the separate control system for each engine is at a common terminal in the main junction box. Refer to the wiring diagram (figure 128).

2. BRIDGE SYSTEM.—The turbo-boost selector, the Pressuretrol, the governor, and the waste-gate motor all contain potentiometers. These potentiometers and the transformer secondaries which supply their voltage are all connected at "J" box terminals to form what is known as the bridge system. The bridge system is the source of all the signals sent to the amplifier to control the waste-gate motor.

3. WASTE-GATE-MOTOR CIRCUIT.—The waste-gate motor contains two field windings. The power for one of these windings is supplied through a condenser directly from the inverter, while the other winding receives its power from the amplifier. The winding which is powered by the amplifier controls the direction of rotation of the motor.

4. AMPLIFIER.—The amplifier is an intermediate unit between the bridge system and the waste-gate motor. It receives and amplifies the signals from the bridge system and translates them into power for one of the field windings in the waste-gate motor.

The control system of each engine has its own amplifier. When testing the control system for any one engine, the amplifier can be tested as an independent component. The division between the amplifier and the bridge system is at the main "J" box, where one lead carries all signals from the complete bridge circuit to the grid of the 7F7 amplifier tube.

The division point between the amplifier and the waste-gate motor is also at the main "J" box, where one lead from the discriminator circuit in the amplifier connects to one of the field windings of the motor, and another lead from the amplifier fuse connects to the other field winding through a condenser.

(7) LOCATING TROUBLE AFFECTING ONLY ONE ENGINE.

(*a*) PRELIMINARY CHECK.—Perform engine run-up test and inspections on the turbo control system for the engine affected, as outlined at the beginning of the troubleshooting procedure.

(*b*) ELIMINATING THE POWER SUPPLY.—Obviously, if the trouble affects only one engine, the main electrical power supply is automatically eliminated as a possible source of trouble. The transformers which supply the voltages for individual units will be checked along with the units affected.

(*c*) ELIMINATING THE AMPLIFIER AS A COMPLETE UNIT.—If the malfunction reported is a hunt in manifold pressure, or if the waste-gate motor runs (even though not properly) in response to changes of dial settings on turbo-boost selector, the amplifier and the fuse in the amplifier can usually be eliminated as a possible source of the malfunction. In this case, proceed to check the bridge system immediately. (Refer to paragraph (*d*) following for method of checking the bridge system.) However, if the waste-gate motor does not run, make these tests:

1. Remove the amplifier from its case and check the fuse. If fuse is O.K., connect the spare amplifier into the circuit, allow two minutes for it to warm up, and then turn the dial of the turbo-boost selector to see if the motor will respond. This test will prove whether the original amplifier was at fault. For a further check of the amplifier, refer to paragraph (*b*).

CAUTION

If the fuse was burned out in the original amplifier, do not connect the spare amplifier into the circuit. Even a momentary overload may weaken and shorten the life of the tubes.

2. If fuse in amplifier was burned out, check the electrical wiring of the turbo control system for a short-to-ground or a short between wires. For a method of finding a short-to-ground or other short circuits in the bridge system, refer to paragraph (*d*) *2* a and (*d*) *2* b following. If no shorts can be found in the bridge system, check the waste-gate-motor circuit for a short between wires or to ground. Refer to paragraph (*i*) *3* b.

If no shorts of any kind can be found in either the bridge circuit or waste-gate-motor circuit, replace the amplifier with the spare and again test the operation of the system. Low emission of both 7C5 tubes in an amplifier may result in blowing a fuse.

3. If the fuse is good and the waste-gate motor still fails to respond after the spare amplifier is connected, replace the original amplifier and proceed to eliminate the bridge system. For method of checking the bridge system as a complete unit, refer to next paragraph.

(*d*) ELIMINATING THE BRIDGE SYSTEM AS A UNIT.

1. If waste gate remains in open position and does not move:

a. Turn calibrator on turbo-boost selector to full clockwise position. Make sure that calibrator wiper has not been forced beyond stops at end of potentiometer winding. (Range of calibration should be 270 angular degrees between stops.)

b. Using an a-c voltmeter (25-volt scale), read voltage from grid to ground across the complete bridge at terminals in the main "J" box. (For example, voltage is read from $\boxed{A1}$ to $\boxed{B8}$ if checking the bridge for engine No. 1, and from $\boxed{A2}$ to $\boxed{B8}$ if checking for engine No. 2, etc.)

NOTE

The following overall bridge voltages and the Pressuretrol voltages are based on sea-level conditions, with approximately 30 inches atmospheric pressure on the Pressuretrol. As the voltage picked up by the Pressuretrol varies approximately 1.7 volts per inch of change in pressure, variations in overall voltage can be expected accordingly. The same effect holds true for the position of the waste gate. At sea level, with engines off and normal operational setting of calibrators, the waste gates should be fully open, even with a dial setting of "8." However, if the air base is at 5,000 feet, when the dial is set at "8" the waste gates should be about half closed, because of an additional signal of approximately 8 volts put in by the Pressuretrol.

c. With dial at "0" (turbos off), voltmeter should read approximately 20 to 21 volts. (At an altitude of 2,000 feet, the reading should be approximately 17 volts.) When dial is turned clockwise, voltage should decrease to zero at approximately "7" on the dial (at position "6" when at 2,000 feet altitude, etc.), then build up again to approximately 9 volts (approximately 12 volts at 2,000 feet altitude, etc.) when "10" is reached. If this variation is obtained and waste gate does not move, the bridge system is *not* at fault. However, if voltage cannot be reduced to zero or does not vary as described, the bridge system is at fault. To isolate trouble to a definite unit in the bridge system, use the procedure given in paragraph (*f*) following.

2. If waste gate is closed and does not move:

a. Turn calibrator on turbo-boost selector to full clockwise position, checking to see that a stop is reached. If no stop is reached, the wiper must have been forced beyond the stops at the end of the potentiometer winding. If the calibrator potentiometer has been damaged, replace the turbo-boost selector.

b. With calibrator in full clockwise position, read voltage from grid to ground across the complete bridge at terminals in the main "J" box. (Use 50-volt scale.) With dial at "0" (turbos off), voltmeter should read approximately 33 volts. When dial is turned clockwise, voltage should drop steadily to 3 volts at "10," without reaching zero voltage.

c. If waste gate remains closed when dial is at "0" and voltage is from 30 to 33 volts, the bridge system is not at fault. Check the amplifier next.

d. If, however, voltage does not read 30 or more volts with dial at "0," proceed to isolate the trouble within the bridge system.

3. If waste gate is only partly closed and does not move when dial is turned:

a. With dial at "0," voltage across the bridge from grid to ground should be between 20 and 33 volts, depending on position of the wiper of the balancing potentiometer. If waste gate is half closed, voltage should be about 26 or 27 volts from grid to ground.

b. Follow the steps used in checking the closed waste gate.

4. If waste gate moves but does not open at the proper dial setting:

a. Check bridge voltages with motor nearest closed position and also with motor in open position. With calibrator turned clockwise and dial at "10," waste gate should go one-half closed and bridge voltage should be zero.

b. With dial at "0" and waste gate fully open, voltage across bridge should be approximately 20 volts. When dial is turned back toward "8," waste gate should first start to close at approximately "7."

c. If motor responds to dial movement, the balancing potentiometer will cancel out any bridge voltages between extreme open and closed positions. Therefore, it is necessary to check voltages only at the two extreme dial settings.

(*e*) ELIMINATION OF WASTE-GATE-MOTOR CIRCUIT AND LINKAGE AS A COMPLETE UNIT.—If the trouble is proved to be in the turbo control system, and the complete bridge system and amplifier have been eliminated, the difficulty must be in the waste-gate-motor circuit or the waste-gate linkage. Refer to paragraph (*i*) following for method of isolating trouble found to be in the waste-gate-motor circuit.

CAUTION

Never disconnect AN connector of waste-gate motor when inverter is on because this is apt to damage the amplifier tubes.

(*f*) HOW TO ISOLATE TROUBLE TO A DEFINITE UNIT WITHIN THE BRIDGE SYSTEM.—If the trouble is known to be somewhere in the bridge system, it can be isolated to a small area by a complete voltage check of each section of the system. A few malfunctions, however, will not be revealed by a voltage check. In this case, make a complete resistance check, as given in paragraph 2 following.

After isolating the trouble to a small area surrounding one unit, check the continuity of the wires in that area to make sure the wires leading to the unit involved are O.K. Where wing disconnects are used, a check should be made to insure continuity of leads from main "J" box to nacelle "J" box. If all leads are O.K., replace the unit involved.

1. TO MAKE A VOLTAGE CHECK.

NOTE

The following voltages are based on 115-volts supply. If transformer *primary voltage* is less than 115 volts, the voltages will be reduced accordingly.

a. Check turbo-boost selector first. Turn dial to "10" and calibrator fully clockwise, and then read voltage from calibrator to ground (main "J" box terminals $\boxed{A3}$ to $\boxed{B8}$ if on No. 1 engine, from $\boxed{A4}$ to $\boxed{B8}$ if on No. 2 engine, etc.). With dial at "10" and calibrator clockwise as described, the voltage should be approximately 9 volts. If this reading is 9 volts, then turn the dial counterclockwise. The voltage should decrease to zero voltage at about "7" on the dial, and then build up again to approximately 21 volts as "0" on the dial is reached. If these voltages are obtained, the turbo-boost selector is O.K.

b. If the turbo-boost selector is O.K., leave calibrator set in extreme clockwise position and turn dial to "10." Proceed to nacelle "J" box and read voltage between terminals B6 and B10. This

should read 9 volts, the same as at the main "J" box. This check proves continuity of wire from the main "J" box terminal to nacelle "J" box terminal (wire No. 56 for No. 1 engine).

c. If the turbo-boost selector and its connection to the nacelle "J" box have been eliminated, then check the transformer primary across terminals A1 and B10 of the nacelle "J" box. Voltage should be from 100 to 115 volts. If this voltage is O.K., check remainder of the bridge system. *However, if this voltage is less than 100 volts, check power supply and inverter output.*

d. To check remainder of the bridge system, read voltages between nacelle "J" box terminals indicated in paragraph (*1*) following. If these voltages are not obtained, the trouble is in the unit being checked, or in its connections. Before replacing the unit, check the wires leading from the nacelle "J" box to the AN connector for an open or a short-to-ground. For checking continuity of leads, refer to paragraph (*f*) *3* following; and for locating grounds or shorts within a bridge system, to paragraph (*f*) *2* following.

(*1*) Check Pressuretrol. The voltages should be as follows:

Transformer voltage, B7 to B9 . . 30 volts

Wiper to high-pressure end of potentiometer wiper, B6 to B7 . . . . . 6 volts*

Wiper to low-pressure end of potentiometer wiper, B6 to B9 . . . . . 24 volts

*This depends on the altitude at which it is checked. Six or seven volts would be correct for sea-level condition. About 10 volts would be correct for an altitude of 2,000 feet.

(*2*) Check accelerometer. The voltages should be as follows:

Wiper to far end of potentiometer winding, B9 to B4 . . . . 30 volts

Wiper to dead-spot end of potentiometer winding, B4 to B7 . . . . 0 volts

(*3*) Check overspeed control. Voltages should be as follows:

Wiper to far end of potentiometer winding, B4 to B5 . . . . 24 volts

Wiper to dead-spot end of potentiometer winding, B4 to B3 . . . . 0 volts

Transformer voltage, B3 to B5 . . 24 volts

(*4*) Check balancing-potentiometer connection to the rider winding of the transformer. Voltage should be as follows:

Transformer voltage, B3 to A2 . . 6 volts

(*5*) Check balancing potentiometer. Voltages should be as follows:

Transformer voltage, A2 to B2 . . 12 volts

One end of potentiometer winding to wiper, A2 to B8 . . . . 0 to 1 volts

Other end of potentiometer winding to wiper, B2 to B8 . . . . . . 10 to 12 volts

NOTE

These balancing-potentiometer voltages are correct for open waste gate.

The following examples illustrate the method of isolating a malfunction within a bridge system by using a voltage check. They are purely illustrative, and are not taken from actual malfunction occurrences.

Example 1: All four engine controls had been working satisfactorily until a high-altitude flight. At an altitude of 30,000 feet, the manifold pressure on No. 4 engine dropped off, and no turbo boost could be obtained on No. 4 engine during the remainder of the flight. With dial at "10," inspection revealed that the waste gate remained open. The fuse and the amplifier were then checked and found to be O.K.

The bridge system was checked next. With calibrator turned fully clockwise and dial at "10," the voltage from main "J" box terminals $\boxed{C2}$ to $\boxed{B1}$ was 6 volts. As the dial was turned toward "0," the voltage steadily increased, instead of decreasing to zero voltage at "7." This proved that the bridge system was at fault.

The turbo-boost selector was then checked. With dial at "10," the voltage from $\boxed{C4}$ to $\boxed{B8}$ was 9 volts. As the dial was turned toward "0," at "7" the voltage dropped to zero and then continued to increase again to 20 volts, when "0" on the dial was reached. This showed that the turbo-boost selector was O.K.

The next test was made in the nacelle "J" box. With dial at "10" and calibrator still in full clockwise position, the voltage from nacelle "J" box terminal B6 to terminal B10 showed 9 volts, proving the connection from the main "J" box to the nacelle "J" box was O.K. A check of the power-supply voltage (A1 to B10) showed 110 volts, which was O.K.

Continuing up through the bridge system, the following voltages were read:

B7 to B9 . . . . 29 volts (approximately)

This indicates that the transformer secondary for Pressuretrol bridge is O.K.

B7 to B6 . . . . 5½ volts (approximately)
B6 to B9 . . . . 23 volts (approximately)

The above two voltage readings indicate that the Pressuretrol potentiometer wiper is nearest to terminal B7 , which is the high-pressure end of the winding. This position is normal.

B9 to B4 . . . . 29 volts
B4 to B7 . . . . 0 volts

The latter voltage indicates that the accelerometer potentiometer wiper is at the end of the winding. This is its normal position.

B3 to B5 . . . . 23 volts

This indicates that the overspeed transformer secondary voltage is O.K.

*B4 to B5 . . . . 9 volts
*B4 to B3 . . . . 14 volts

These two voltages indicate that the overspeed potentiometer wiper is closer to terminal B5, which is the far end of the winding. The normal position should be at the end of the winding which connects to terminal B3. With the wiper in its normal position, the voltage measured from B4 to B3 should be zero.

*Obviously, there was something wrong with the overspeed unit or its connection. In this example, it was not necessary to check continuity of the leads to the Pressuretrol because the sum of the voltages from the potentiometer wiper to each end of the potentiometer winding equaled the total potentiometer voltage (23 volts). These voltage readings proved that the circuit was complete.

As the connections proved O.K., the only solution was to replace the complete governor. When the governor was removed and the overspeed potentiometer inspected, it was discovered that the wiper had run part way up on its winding and, because of clutch failure, had not returned. The complete governor was then replaced and the defective unit sent to a Fourth Echelon repair station for overhaul.

Example 2: At an altitude of approximately 20,000 feet the manifold pressure on No. 2 engine started running high and did not appear very stable. This was the highest altitude to which the airplane ascended. Upon descent, the manifold pressure started increasing quite rapidly on this engine, and had to be reduced with the throttle.

After landing, inspection revealed that the waste gate was approximately half-closed, with dial at "8," calibrator set in its original position, and engines off. With calibrator turned fully clockwise, the dial had to be turned back to "3" before the waste gate opened, whereas the gate should have been open at "7." The amplifier, the fuse, and the waste-gate motor were automatically eliminated as the source of trouble because the waste gate moved when the dial was turned.

With calibrator fully clockwise and dial at "10," the waste gate was closed, and the voltage from A2 to B1 was 9 volts. As the dial was turned counterclockwise, the waste gate gradually opened, but the full-open position was not reached until the dial was at "3." The bridge system was apparently at fault. This conclusion was verified by the voltage reading of 9 volts at position "10."

When the turbo-boost selector was checked, the voltage from A4 to B8, with dial at "10," was 9 volts. As the dial was turned counterclockwise, the voltage dropped to zero at point "7" on the dial, and then increased again as "0" on the dial was reached. These tests proved that the turbo-boost selector was normal. Repeating this check on terminals B6 and B10 in the nacelle "J" box gave the same results.

A check of the power-supply voltage from A1 to B10 indicated a supply of 110 volts. Continuing up through the bridge, the following voltages were read:

B7 to B9 . . . . 29 volts

This proves transformer secondary voltage on Pressuretrol bridge is O.K.

*B7 to B6 . . . . 17½ volts
*B6 to B9 . . . . 11 volts

By this test, the position of the Pressuretrol potentiometer wiper is located. Wiper is apparently closer to B9, which is the low-pressure end of potentiometer winding.

B9 to B4 . . . . 29 volts
B4 to B7 . . . . 0 volts

Zero voltage from B4 to B7 indicates that the wiper of the accelerometer potentiometer is at the end of the winding, which is its normal position.

B3 to B5 . . . . 23 volts

This checks the transformer secondary voltage applied to the overspeed potentiometer.

B4 to B5 . . . . 23 volts
B4 to B3 . . . . 0 volts

The latter voltage locates position of the overspeed potentiometer wiper on winding. Zero voltage indicates that it is at the end of the winding, where it should be.

*Obviously, the Pressuretrol was at fault. Since the two voltages from the potentiometer wiper to the ends of the winding totaled 29 volts and all the rest of the bridge voltages were O.K., it was quite apparent that the Pressuretrol wiper was not in its proper position to register carburetor intake pressure, which would be atmospheric pressure on the ground with engines off. If the trouble had been in the connections leading to the Pressuretrol, the voltages from the potentiometer wiper to each end of the winding probably would not have totaled up to the total potentiometer voltage.

The Pressuretrol was uncovered and the position of the wiper observed before any further checking was done. A look inside the Pressuretrol showed the wiper just above the center of the winding. This was incorrect, as the barometric pressure at that base was 29.5 inches Hg. With a pressure of 29.5 inches, the wiper should be below center and close to the bottom of the potentiometer winding. Apparently the wiper had not been properly tight-

ened on the shaft when assembled at the factory. As this wiper cannot be repositioned without recalibrating the instrument, the complete Pressuretrol was replaced.

2. TO MAKE A RESISTANCE CHECK.

CAUTION

Power must always be off when making a resistance check.

a. CHECK FOR A SHORT-TO-GROUND.

(*1*) Turn off inverter switch.

(*2*) Disconnect lead to calibrator wiper of the turbo-boost selector. (If on No. 1 engine, remove PC45 from terminal A3; if on No. 2 engine, disconnect PC46 from A4; etc.)

(*3*) Check remainder of bridge circuit to ground, using main "J" box terminals. (Ohmmeter should read approximately 50,000 ohms.)

For No. 1 engine, check A1 to B1

For No. 2 engine, check A2 to B1

For No. 3 engine, check C1 to B1

For No. 4 engine, check C2 to B1

If resistance is less than 50,000 ohms (plus or minus 20%), go to nacelle "J" box and check down through bridge terminals until point of lowest resistance to ground is found. Use B10 as ground terminal in nacelle "J" box. Disconnect wires from terminal having lowest resistance and check each wire to ground. When wire of lowest resistance is found, disconnect the other end of the wire also and again read resistance to ground. This check must be performed to determine whether the wire itself is grounded or whether the ground is in some unit to which the wire is attached. If the wire leads to one of the operational units, the other end of the wire can be disconnected by removing the AN connector.

b. CHECK FOR A SHORT OR AN OPEN.—A short between certain wires in the same bridge circuit or an open between a potentiometer wiper and the winding may not show up on a voltage check. Conversely, a resistance check may fail to reveal lack of proper voltage. After isolating the malfunction to the bridge circuit, if the voltage check and the check for a short-to-ground failed to reveal the trouble, check the complete bridge system with an ohmmeter.

Nacelle "J" Box Terminals

With power off, approximate resistance values should be:

Pressuretrol potentiometer:

B6 to B7 . . . . . 108 ohms

B6 to B9 . . . . . 105 ohms

Accelerometer potentiometer:

B4 to B7 . . . . . 0 to 1 ohm

B4 to B9 . . . . . 6.5 ohms

Overspeed potentiometer:

B4 to B5 . . . . . 20 ohms

B4 to B3 . . . . . 0 to 1 ohm

*Waste-gate-motor balancing potentiometer:

A2 to B8 . . . . . 0 to 100 ohms (with waste gate open)

B2 to B8 . . . . . 0 to 100 ohms

*When the waste-gate motor strikes the stop, the balancing-potentiometer wiper usually is a slight distance from the end of the potentiometer winding. This accounts for very indefinite resistance readings. However, a reading of 100 ohms or less proves that the wiper is making contact. If the wiper failed to contact the winding, the resistance reading would be approximately 50,000 ohms.

Main "J" Box Terminals

With dial of turbo-boost selector at "8" and normal calibration setting, with power off, resistance should be as follows:

Engine No. 1, A3 to B8 : approx. 625 ohms

For other engines, use corresponding main "J" box terminals. The resistance value should be the same for all engines.

3. CHECK CONTINUITY OF WIRES LEADING TO A GIVEN UNIT.—After isolating the cause of a malfunction to a small part of the system, it is frequently necessary to test the continuity of leads to determine whether the trouble lies within some unit or whether it is in the wiring.

To check continuity of long leads from a "J" box terminal to an AN connector, turn off the power. Then remove the AN connector to which the lead is fastened. The continuity test can be made from the "J" box by using a device to connect two pin-sockets. It is suggested that a piece of insulated wire

about 3 inches long with an AN-connector pin soldered to each end be used for this purpose.

(*g*) HOW TO TEST FOR A SHORT BETWEEN TWO BRIDGE SYSTEMS.—With power off, disconnect the AN connector of the turbo-boost selector and test resistance between the two bridge systems which are in question. This can be done by checking between two similar main "J" box terminals, one of which is in each bridge. The following examples illustrate this method.

Example 1: To check for a short between No. 1 turbo control and No. 2 turbo control, read the resistance from A3 to A4. This resistance should be at least 100,000 ohms, as the two bridge systems should not be connected except through the two 50,000-ohm ground resistors.

If this check indicates that the two bridge systems are shorted together, separate the leads from the terminals being tested and check between the individual leads to find out which leads are shorted. Continue to isolate this short by separating both ends of the leads from the units to which they are connected and again testing between them. If they are shorted together, the ohmmeter should register a very low resistance. If, however, the short exists within some unit and not between the wires, the short will disappear when both ends of the wires have been disconnected. Continue this process up through the bridge until the actual short is found.

Example 2: Variations of manifold pressure on No. 1 engine were also reflected on No. 2 engine. With the AN connector of the turbo-boost selector removed, a check from A3 to A4 showed zero resistance, indicating a short. The leads on A3 and A4 were then disconnected and checked individually.

PC45 and PC46 showed no connection to PC56 or PC61. However, a check between PC56 and PC61 showed zero resistance. These two leads were then disconnected from B6 in the two nacelle "J" boxes. A check between the two wires revealed that the short still existed; the two wires were shorted together somewhere between the main "J" box and the nacelle "J" boxes. Since these two wires run in close proximity in some installations, a breakdown of the insulation occurring at some point through wear or deterioration might cause a short between the two bridges.

(*h*) ISOLATING TROUBLE FOUND TO BE IN THE AMPLIFIER.

1. Check the fuse and fuse contacts. Corrosion may have caused an open circuit at the fuse, or a connection may have become unsoldered.

2. Check tubes by substituting new tubes one at a time to see if the amplifier starts working.

3. If the trouble has been isolated to the amplifier and the fuse is burned out, look for shorted wires. If no short is visible, try replacing both 7C5 tubes, as gaseous 7C5 tubes may burn out the fuse. (*To avoid future tube trouble, always replace 7C5 tubes in pairs.*) A gaseous tube will usually be indicated by low emission when tested in an ordinary tube tester.

4. Minor repairs can be made even in flight if a spare amplifier is not available. If the malfunction is more serious than those described here, replace the complete amplifier.

(*i*) ISOLATING TROUBLE FOUND TO BE IN WASTE-GATE-MOTOR CIRCUIT.

1. Check the amplifier-phase voltage. Turn dial until bridge voltage is 2 volts with motor against one of its stops or in some fixed position; then read the amplifier-phase voltage across main "J" box terminals (A7 and B1 if on No. 1 engine, A8 and B1 if on No. 2 engine, etc.). Voltage should be 200 volts (plus or minus 20%, depending on inverter-output voltage). However, if the field winding is open, voltage might be as high as 1,000 volts. Disconnect grid lead and repeat voltage check. With no input signal, amplifier-phase voltage should not be less than 45 volts, but it may go as high as 150 volts. With no bridge signal, if voltage is lower than 45 volts, turn power off and read resistance to ground at terminal A7. Resistance reading should be approximately 50 ohms. A lower resistance reading would indicate a short-to-ground.

2. Check the fixed phase of the waste-gate-motor circuit.

a. Reconnect grid lead.

b. Proceed to nacelle "J" box and check condenser in fixed phase by reading voltage between terminals A1 and B1. Voltage should be 300 volts (plus 25%, minus 15%), with motor stopped in open position. If this voltage is not obtained, replace the condenser.

c. To check the fixed-phase winding, read voltage from B1 to B10. Voltage should be 325 volts (plus 75 or minus 25 volts) with motor stopped in open position.

3. If any of the above voltages (except the condenser voltages) are not obtained:

a. Check continuity of wires from nacelle "J" box to motor AN connector.

b. To check for a short-to-ground in the waste-gate-motor circuit, read resistance from nacelle "J" box terminals A3 to B10 and from B1 to B10. The resistance measured from A3 to B10 should be 50 ohms (plus or minus 10%), and from B1 to B10 50 ohms (plus or minus 10%). A resistance considerably less than 50 ohms indicates a ground.

4. Check linkage for binding action.

5. Check condensers in amplifier and nacelle "J" box for leakage.

6. If the trouble is found to be in the motor, or if these tests fail to reveal the exact trouble, replace the waste-gate motor.

(*j*) FINDING THE CAUSE OF A HUNT OR SHARP DROP IN MANIFOLD PRESSURE.—Test operation of engine in flight without turbo boost. If manifold pressure still hunts, even though to a lesser degree, the turbo control system is not at fault. This test should be made at a fairly low altitude, so that sufficient manifold pressure for flight can be maintained without turbo boost.

1. IF TURBO CONTROL SYSTEM IS AT FAULT.—Check the entire bridge system for an intermittent open. This can be done by checking the voltages of all potentiometers, as outlined in paragraph (*d*) *1* c-d. With the engines running at constant speed, note any voltages that fluctuate rapidly as an indication of an intermittent open.

2. IF TURBO CONTROL SYSTEM IS NOT AT FAULT.—Check the following for probable causes:

a. PROPELLER GOVERNORS.—If rpm hunts as well as manifold pressure, change rpm setting several times to test operation of the propeller governor.

b. MIXTURE CONTROL.—Check mixture setting. Improper mixture setting will be reflected in cylinder-head temperatures. Too lean a mixture results in high cylinder-head temperatures, while too rich a mixture results in low cylinder-head temperatures causing the engine to miss. Missing usually is recognized by roughness or vibration of engine.

c. FAULTY IGNITION.—Faulty ignition will cause misfiring of the engine, producing a hunt in rpm and manifold pressure. For high-altitude operation, the spark-plug gap should be set so that a thickness wire of .011 inch will go between the points but a wire of .014 inch will not.

d. PREIGNITION AND DETONATION.—Improper adjustment of the intercooler shutters may cause too high a carburetor air temperature, and climbing at too slow a speed may cause too high a cylinder-head temperature. Both conditions will, in time, produce preignition and possible detonation; these in turn are likely to cause a hunt in manifold pressure. The copilot must watch cylinder-head temperatures at all times.

e. CARBURETOR ICING.—Carburetor ice will cause a rapid drop in manifold pressure. This can be prevented by use of 3 or 4 inches of turbo boost whenever the atmosphere contains sufficient moisture to form ice. If ice begins to form, closing the intercooler shutters should soon restore manifold pressure. Refer to pilot's operating instructions, page 2.

f. MAGNETOS.—A faulty magneto may cause "galloping" of the engine, thereby producing a hunt in manifold pressure. One of the most accurate checks for magneto or other ignition trouble is to watch a reference point on the cowling against another point on the nacelle for a twisting movement, indicating engine roughness.

(*k*) LOCATING TROUBLE WHEN THE CONTROL SYSTEM FAILS TO FUNCTION ON ALL ENGINES.

1. Check to see if inverter is running.

2. Check voltage output of inverter ($\boxed{\text{B4}}$ to $\boxed{\text{B10}}$ in the main "J" box). If voltmeter indicates no voltage, then check the fuse which links the inverter to the turbo control system. Voltage output of inverter should be approximately 115 volts ac.

3. If fuse is O.K., but no voltage is obtained at the main "J" box of the turbo control system, check continuity of wire leading from main "J" box through fuse to inverter.

4. Check ground connection of $\boxed{\text{B4}}$ in the "J" box, and check also ground connection on the inverter a-c supply.

5. Check battery-supply voltage. With engines running and generators on, 28.5 volts should be obtained.

6. If a-c supply voltage is O.K. at the main "J" box, check voltage across turbo-boost selector as described in paragraph 5 *a* (7)(*f*)*1* preceding.

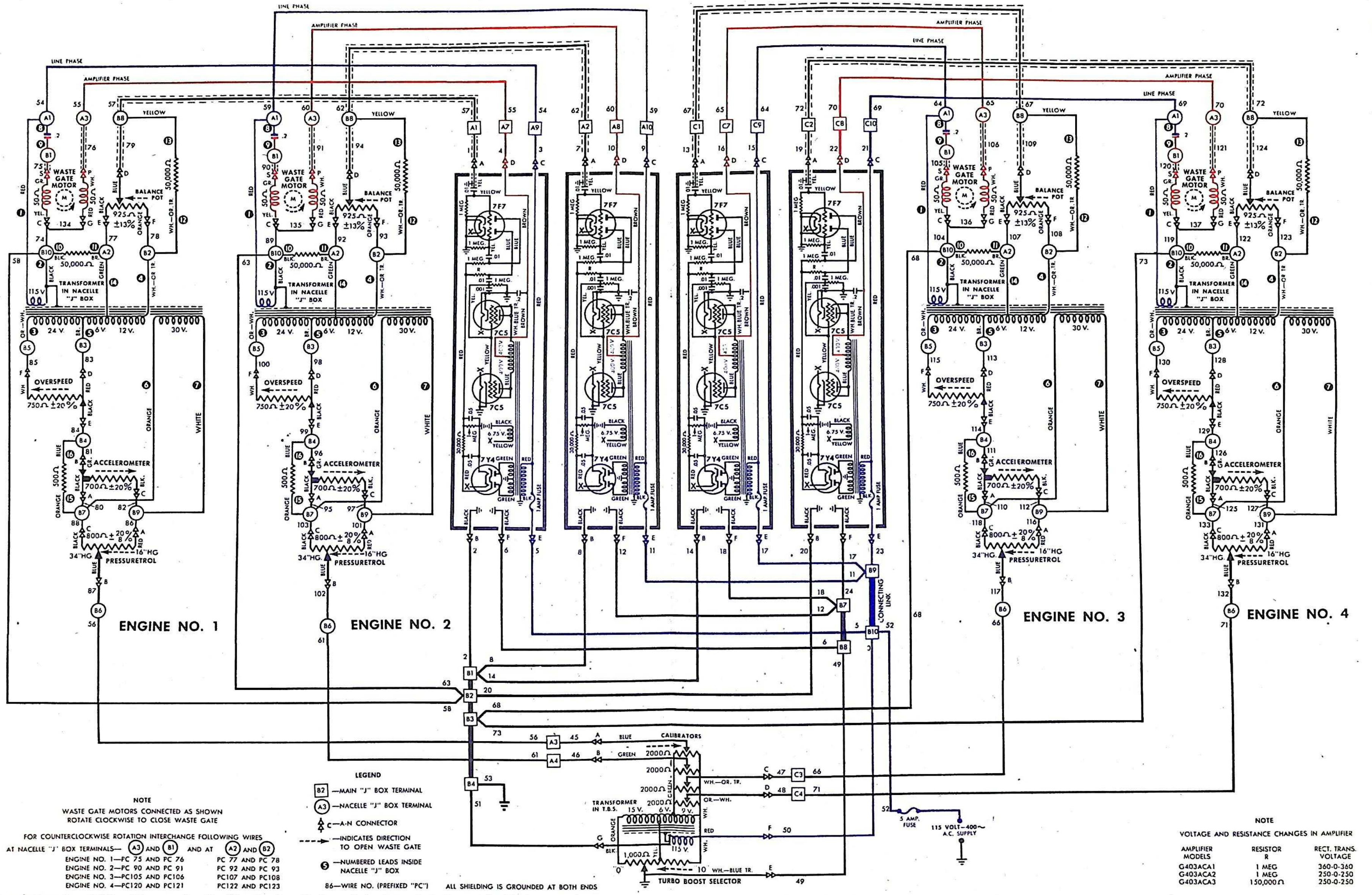
7. If the above checks do not reveal the trouble, check the main junction box for loose connections, and check all cables leading away from the main junction box.

b. SERVICE TROUBLES AND REMEDIES CHART.—The following troubles and remedies chart is intended only as a reminder of some things to look for when performing the 25-hour inspection or engine run-up test as part of the regular systematic trouble-shooting procedure.

This chart should NOT be used for a trial-and-error method of troubleshooting, and it is not intended to replace the systematic troubleshooting procedure. When any of the given symptoms are noted, the standard troubleshooting procedure should be used to determine which of the possible causes is the real cause. The trouble then can be remedied as suggested on the chart.

TROUBLE	CAUSE	REMEDY
MANIFOLD PRESSURE FALLS OFF ABNORMALLY AS AIRPLANE CLIMBS	Leaks in induction system.	Repair or replace defective part of induction system.
	Obstructions in air scoop or air filter.	Remove obstructions.
	Leaks in exhaust stack.	Repair or replace part causing trouble.
	Fuse blown—waste gate stopped at partly closed position. Mechanical failure of waste-gate linkage.	Check turbo control system for shorts and grounds, faulty condensers, or mechanical failures, and make repairs or replacements as needed.
	Electrical troubles in bridge system.	Check bridge system for opens, grounds, or shorts. See troubleshooting procedure.
	AN connector loose on some unit.	Insert properly and tighten.
	Pressuretrol AN connector inserted in wrong position.	Check alignment with guide key.
	Failure of a tube in the amplifier.	Replace tube.
MANIFOLD PRESSURE INCREASES AS AIRPLANE CLIMBS, OR IT IS ABNORMALLY HIGH ON ONE OR MORE ENGINES	Leaky connection in Pressuretrol tubing.	Tighten or replace tubing and connections as needed.
	Faulty Pressuretrol operation.	Replace Pressuretrol.
	Low voltage or faulty 7C5.	Locate by using troubleshooting procedure, and repair or replace part affected.
	Electrical troubles in bridge system.	Locate by using troubleshooting procedure, and repair or replace part affected.
MANIFOLD PRESSURE "HUNTS" AT LOW ALTITUDE	Faulty Pressuretrol operation.	Replace Pressuretrol.
	Faulty propeller-governor operation.	Run prop through full rpm range. If this doesn't remedy the condition, refer trouble to propeller-governor maintenance men.
	Engine ignition system troubles.	Repairs or replacements to be made by engine maintenance crew.
	Faulty accelerometer inertia spring.	Repair or replace governor.
	Break in balance or Pressuretrol potentiometer winding.	Replace defective unit.
	Intermittent open or ground in bridge system.	Repairs or replacements to be made by engine maintenance crew.
	Loose waste-gate linkage.	Tighten or replace part affected.
	Dirt under wiper of accelerometer potentiometer.	Replace governor, or clean potentiometer winding.
	Air-filter gates "flapping."	Repair gate-operating mechanism.

TROUBLE	CAUSE	REMEDY
MANIFOLD PRESSURE "HUNT" MORE PRONOUNCED AT HIGH ALTITUDE	Turbo governor not smooth in overspeed range.	Replace governor.
	Dirt under wiper of accelerometer potentiometer.	Replace unit.
	Ignition-system troubles.	Repairs or replacements to be made by engine maintenance crew.
	Propeller-governor troubles.	Repairs or replacements to be made by engine maintenance crew.
	Carburetor troubles.	Repairs or replacements to be made by engine maintenance crew.
	Faulty Pressuretrol.	Replace Pressuretrol.
MANIFOLD PRESSURE OVERSHOOTS WHEN THROTTLES ARE ADVANCED RAPIDLY	Accelerometer not operating.	Replace governor or flexible drive.
	Pressuretrol not operating properly.	Replace Pressuretrol.
	Propeller governors not operating properly, allowing rpm to overshoot.	Repairs or adjustments to be made by proper maintenance crews.
MANIFOLD PRESSURE FALLS OFF AT HIGH ALTITUDE AND THEN STAYS BELOW NORMAL DURING REMAINDER OF DESCENT, OR UNTIL THROTTLE RANGE IS REACHED	Overspeed potentiometer wiper stuck part way up on winding.	Replace governor.
	Governor out of calibration.	Replace governor.
	Leak in induction.	Repair or replace faulty part.
	Ice in carburetor.	Close intercoolers, increase turbo boost.



NOTE

WASTE GATE MOTORS CONNECTED AS SHOWN ROTATE CLOCKWISE TO CLOSE WASTE GATE

FOR COUNTERCLOCKWISE ROTATION INTERCHANGE FOLLOWING WIRES

AT NACELLE "J" BOX TERMINALS— (A3) AND (B1) AND AT (A2) AND (B2)

ENGINE NO. 1—PC 75 AND PC 76 — PC 77 AND PC 78
ENGINE NO. 2—PC 90 AND PC 91 — PC 92 AND PC 93
ENGINE NO. 3—PC105 AND PC106 — PC107 AND PC108
ENGINE NO. 4—PC120 AND PC121 — PC122 AND PC123

LEGEND

B2 —MAIN "J" BOX TERMINAL
A3 —NACELLE "J" BOX TERMINAL
C —A-N CONNECTOR
—INDICATES DIRECTION TO OPEN WASTE GATE
5 —NUMBERED LEADS INSIDE NACELLE "J" BOX
86—WIRE NO. (PREFIXED "PC")

ALL SHIELDING IS GROUNDED AT BOTH ENDS

NOTE

VOLTAGE AND RESISTANCE CHANGES IN AMPLIFIER

AMPLIFIER MODELS	RESISTOR R	RECT. TRANS. VOLTAGE
G403ACA1	1 MEG	360-0-360
G403ACA2	1 MEG	250-0-250
G403ACA3	150,000Ω	250-0-250

Figure 128—Complete Wiring Diagram for Modification Installations of the Type B-3 Control for Turbosuperchargers

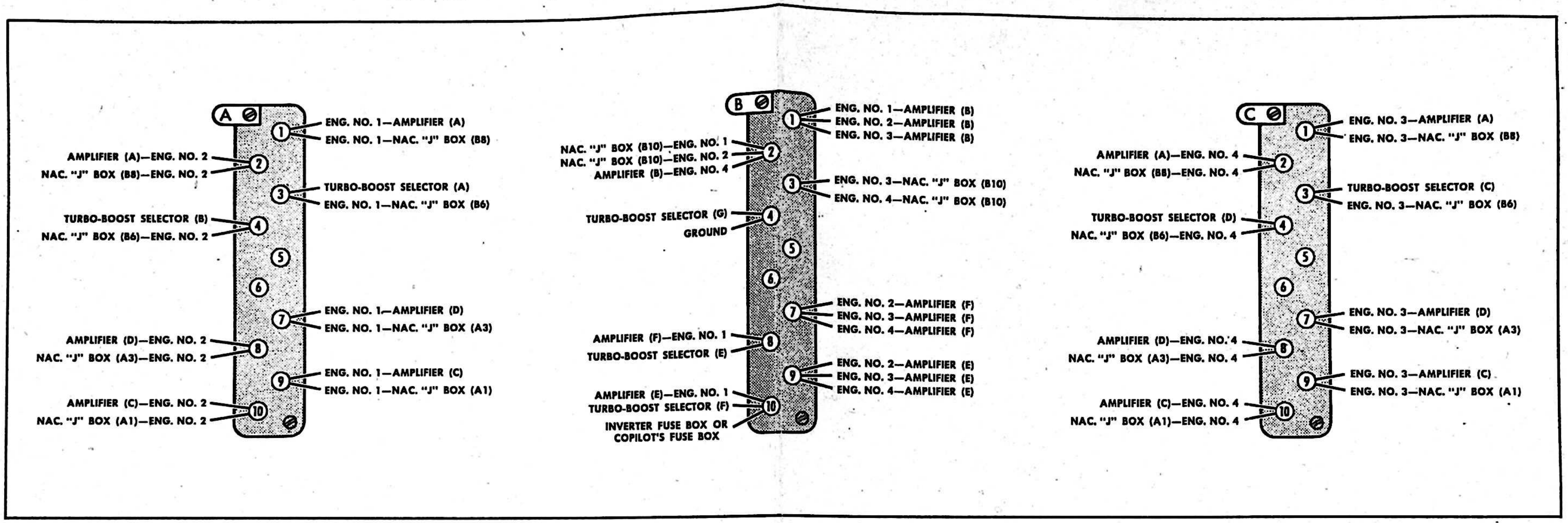


Figure 129—Main Junction Box Connection Diagram

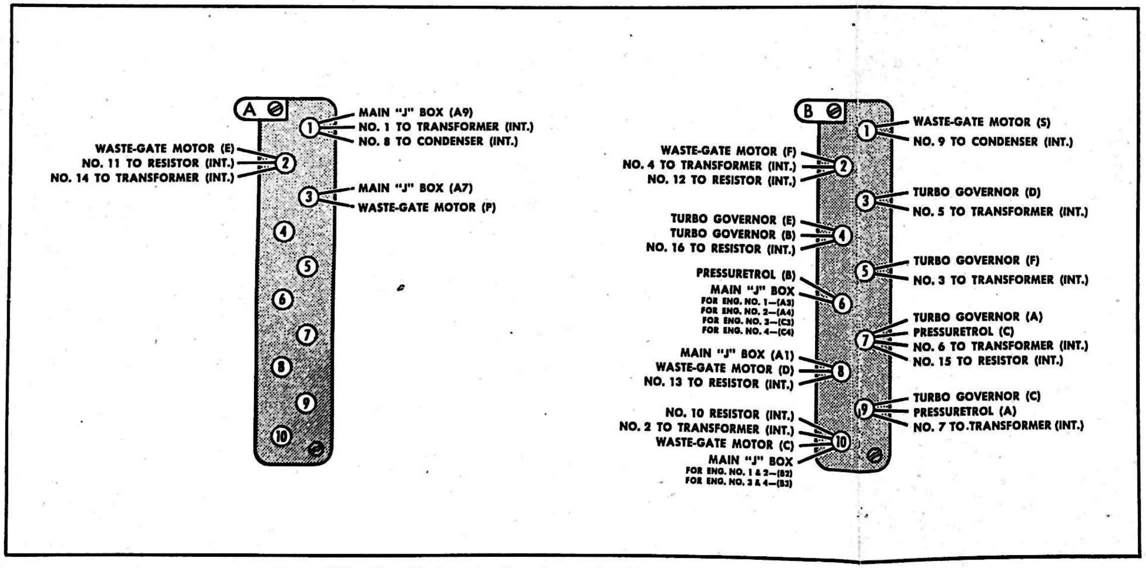


Figure 130—Nacelle Junction Box Connection Diagram

LEGEND

Figure 129:

The diagram of the Main "J" Box of a four-engine control system shows the three terminal blocks and the wires attached to each terminal. Each wire is traced to its destination in the system. Wire numbers are not given, as they may differ in various installations.

Figure 130:

The diagram of a Nacelle "J" Box of the turbo control system shows the two terminal blocks and the wires attached to each terminal. Each wire is then traced to its destination in the system. (Alternate destinations are shown in cases where they vary for each engine of the 4-engine system.) Wire numbers are given for the internal wiring (abbreviated INT. in the diagram). Other wire numbers are not given, as they differ for each engine and may also differ in various installations.